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Interim Technical Report

MAN SYSTEM CRITERIA FOR EXTRATERRESTRIAL ROVING VEHICLES

Phase IB—The LUNEX II Simulation

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MAN SYSTEM CRITERIA FOR EXTRATERRESTRIAL ROVING VEHICLES

Phase IB - The LUNEX II Simulation
(MSFC Contract NAS8-20006)

Prepared by:

J. E. Haaland

Contributors:

H. Y. Grubbs,
NASA Technical Monitor
M. J. Vaccaro, NASA
C. P. Graf
T. J. Kuechenmeister
J. W. Beigle
R. D. Kinkead
A. C. Tuk
S. P. Stackhouse
F. Macek

Approved by:

W T Sackett for
Lorenz P. Schrenk, Ph. D.
Supervisor

Neal M. Burns.
Neal M. Burns, Ph. D.
Principal Investigator

WS M. A. Sutton
M. A. Sutton, Ph. D.
Director of Research

Honeywell Inc.
Systems and Research Division
Minneapolis, Minnesota

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ABSTRACT

An 18-day lunar surface mission was simulated under laboratory conditions with two NASA engineers as test subjects. The purpose of the simulation was to validate a minimum-volume cabin design for a lunar roving vehicle. The cabin contained a free volume of 3.26 cubic meters (115.3 cubic feet) in the main living space and 1.36 cubic meters (48 cubic feet) in the airlock. The cabin had a maximum floor-to-ceiling height of 166.0 centimeters (65.4 inches). The cabin was evaluated with subjects performing representative scientific and mission-oriented tasks in accordance with crew mission timelines developed in connection with this study. A 16-hour on and 8-hour off work-rest schedule was used. Subjects were given a 3000-calorie per day diet provided in four meals per day.

The subjects were evaluated by performance and physiological measures. Driving, monitoring, navigation, sample measurement and audio balancing tasks were performed. Selected geophysical tasks requiring simple but realistic measures contributed to simulation realism. Subjects' maximum oxygen capacity and the associated heart and respiratory rates were obtained before and immediately after the simulation by measuring oxygen consumption during graded treadmill runs. By this means, each subject was physiologically calibrated and pre- and post-simulation physical fitness evaluated. Throughout the simulation heart and respiratory rates were also taken continuously via a biotelemetry system.

Water balance and urine analyses were performed. Selected simulated emergencies were performed to evaluate the interaction of the subjects in pressurized state-of-the-art Apollo suits with the vehicle interior volumes and workspace layout. Subjects performed daily extravehicular activities while wearing inflated pressure suits. Representative physiological stresses were obtained during extravehicular activities by performing walks up to 4.15 kilometers per hour (2.6 miles per hour) on a treadmill while wearing inflated

pressure suits. All simulated tasks were performed at 1 atmosphere pressure. The performance data was analyzed by simple statistics, daily means and standard deviations being calculated by computer for each principal task. Graphical analysis was used to evaluate trends or irregularities in the task data.

No adverse trends or marked irregularities were noted in the performance data of either subject throughout the 18-day simulation. Both subjects maintained satisfactory performance levels and physical condition throughout the simulation with no adverse effects attributable to the extended period of living and working in the vehicle simulator being observed.

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SECTION 1
INTRODUCTION

In earlier studies (Ref. 1) a series of simulations were conducted using a variable-volume simulator to establish preliminary cabin free-volume design criteria for lunar surface vehicles. Using performance and physiological measures (Refs. 1, 2, 3 and 4) in evaluating vehicle interior volumes during a series of 3-hour, 10-hour and 72-hour simulations, a minimum free volume was determined which did not seriously compromise either the subjects' performance of simulated mission tasks or their physical well being. The data, obtained on two-man crews performing representative lunar mission segments, provided critical design data for over-all size, weight and trans-lunar stowage space required for a lunar surface vehicle. These parameters in turn affect the amount of space available on such a vehicle for scientific equipment and lunar surface sample collection.

Though many confinement studies in space cabin simulators have been conducted (Refs. 19, 27, 28 and 29), only one other study is known to have explicitly examined the problems of minimum cabin volume for a two-man crew (Ref. 19). For the present study, a simulator (designated the LUNEX II) was constructed on the basis of the results of the previous short-term simulations.

The LUNEX II was designed to simulate a lunar mobile laboratory, one of several concepts NASA is evaluating for manned lunar exploration. This lunar vehicle is intended to house a two-man crew in a shirt-sleeve environment for a nominal 14-day lunar mission with a maximum stay-time of 21 days. During this mission the crew would conduct a scientific lunar exploration requiring extra-vehicular excursions in pressurized suits on the lunar surface. Crew members would also perform on-board scientific system monitoring and preliminary analyses of lunar surface samples. In addition, vehicle driving, navigation, system monitoring and routine housekeeping tasks would need to be performed. The stationary LUNEX II simulator housed two test subjects for a full-term 14- to 21-day lunar surface mission requiring the performance of tasks related to the lunar mobile laboratory concept. No attempt was made to provide a completely closed ecological system or to simulate unusual environmental conditions.

The test subjects were highly motivated NASA scientist/engineers. The LUNEX II simulator cabin interior incorporated the previously determined minimal cabin volumes into an integrated workspace design as an initial approach to establishing realistic design criteria.

The principal purposes of this simulation were:

- To validate the results of previous short-term studies, using a vehicle of minimal volume, by evaluating crew performance during a two- to three-week simulated lunar surface mission by means of behavioral and physiological tests.
- To develop and validate manned system design criteria for lunar surface cabin interiors.

Shirt-sleeve, ventilated and pressurized suit conditions were evaluated in the context of simulated normal and emergency activities.

SECTION 2
STUDY METHODS AND RATIONALE

2.1 DESCRIPTION OF THE LUNEX II SIMULATOR

The LUNEX II simulator is divided into two compartments -- a driving and work-space/living area having 3.26 cubic meters (115.3 cubic feet) of free workspace and an airlock designed such that, under normal mission conditions, its free workspace volume is 1.36 cubic meters (48.0 cubic feet). The airlock provides 1.86 cubic meters (65.9 cubic feet) during emergency conditions requiring pressure suit use.(The airlock was designed such that under emergency conditions requiring the use of inflated pressure suits the suit and backpack storage space in the airlock would be available for use). The driving and workspace/living area provides 1.63 cubic meters (57.6 cubic feet) per man. The two cabin compartments have a total free volume, under normal conditions, of 4.61 cubic meters (163.3 cubic feet) with an additional 3.96 cubic meters (140.3 cubic feet) of equipment/storage space. These volumes are summarized in Table 1. The crew/cabin space is designed to provide the crew with maximum free work space in the seated position. An unrestricted standing position was not provided since the ceiling height was only 166 centimeters (65.4 inches) (90 percent of the standing height of a 95th percentile man-Ref. 5). The LUNEX II is basically a cylindrical plywood/masonite structure having an inside diameter of 2.1 meters (7 feet) and a floor area of 2.47 square meters (26.6 square feet) (see Figures 1, 2, 3 and 4).

Since the simulation was concerned only with cabin interior space habitated by the test subjects and the space necessary for storing scientific and life support equipment used daily, the unused spaces below the floor and above the ceiling were omitted. Assuming a completely cylindrical vehicle, the entire body would have a volume of 11.08 cubic meters (392.9 cubic feet), with 2.51 cubic meters (89.3 cubic feet) independent of the crew occupied area allotted for vehicle system equipment and accessory gear not directly associated with crew/task activities (see Figure 5).

A driving station (Figure 6) occupied the front of the vehicle and was used for simulated driving (Figure 7) and monitoring tasks (Figure 8). Part of this area was used during sleep periods. Two eccentrically pivoted chairs were located in the driving station, either of them capable of being turned 180 degrees to form a seat usable in the central workspace station (Figures 6, 7, 8 and 11). Stowage space was provided under and to the outside of each chair. Sliding writing boards and storable arm rests were available to each subject when facing forward in the driving seats.

The workspace/living area served as the primary area for performing scientific tasks, preparing and consuming meals, and sleeping. Workspace was available on each side of the center aisle (Figures 9 and 10). A stowable work surface extended across the center aisle accessible to both subjects (Figure 11). A small traveling stool could be pulled from its wall stowage space for sitting in the center aisle area (Figure 12). The maximum standing height in the center aisle was 166 centimeters (65.4 inches). This area served as the sleeping space when a recessed upper bunk was pulled out. One subject slept on the floor and the other on the bunk (Figure 13). Stowable mattresses were provided.

The airlock provided space for pressure suit donning and doffing (Figure 14 and 15). In addition, personal waste elimination was effected in the airlock. Urine and fecal wastes were passed to the outside experimenters for analysis via a sliding compartment (Figure 16). A double-acting door (55.8 cm x 127 cm), capable of opening either into the airlock or the cabin, separated the airlock from the living/workspace area. The outer airlock door (76.2 cm x 127 cm) opened to the exterior of the vehicle. The airlock hatches were opened and secured by 12-inch handwheels with a 55-degree travel to the locked position and a 120-degree travel to the unlocked position (i.e. 65 degrees of overthrow). A constant 12-inch-pound torque was required to operate the outer airlock hatch and 6 inch-pounds were required to operate the inner hatch.

2.1.1 Comestibles and Crew Hygiene Facilities

The subjects' food consisted of dehydrated food in individually packaged meals prepared by the Pillsbury Company. The diet was prepared in advance for five-day cycles and allowed each man approximately 2,800 calories per day consumed during four meal periods each day (Figure 17). Vitamin pills were provided daily as a diet supplement. Enough food for a 21-day simulation was stored in the LUNEX II prior to the start of the simulation. Hot meals were prepared by adding water pre-heated to 140°F to the plastic meal container. Both hot and cold water were available in unrestricted amount. The subjects, however, were required to keep an accurate log of all water consumed both in their meals and as a supplement to the diet. A modified graduated burette capable of providing measured amounts of both hot and cold water was provided for this purpose (Figure 18).

The procedure used in preparing a meal required that the subject tear the top of the plastic sack containing the desired meal item, add the proper amount of hot or cold water, roll down the open end of the plastic sack and seal it with a clip, mix the food and water and ingest it by drinking (or squeezing) the food directly from the plastic sack container.

Waste products were removed using the sliding toilet compartment in the airlock. The subjects urinated into labelled containers which were refrigerated until analyzed. Feces were removed in waterproof bags and frozen for later analysis.

The LUNEX II was ventilated with purified cool air furnished at a flow rate which provided a complete air exchange in 25 to 90 seconds. Louvered intake vents permitted the subjects to control the inlet flow rate and thus permitted them limited control over cabin temperature. Several exhaust vents permitted a rapid exchange of habitable air without danger of contaminant buildup or obnoxious odors. Cabin temperature was measured continuously. The subjects were permitted personal hygiene items with the exception that shaving equipment was not provided. An electric toothbrush was provided for oral hygiene.

Commercial premoistened disposable benzyl chloride/alcohol wash towels were used for cleaning. Small wash pans were provided for occasional sponge baths. Clean sets of clothing were stored in the vehicle. The exchange of used items for clean clothes was effected through a pass box in the side of the vehicle.

2.1.2 INSTRUMENTATION

Two push-to-talk communications stations were located in the LUNEX II for verbal contact with the test monitors. During inflated pressure suit activities, a separate communication system between the subject in the suit and the test monitors was provided. Vehicle lighting was provided by four spotlights with adjustable intensities in the driving/monitoring area, four guarded fluorescent lights in the workspace/living area, and two guarded fluorescent lights in the airlock. The illumination provided in each of these areas is shown in Table 2. Table 3 lists the electrical controls and indicators located in the simulator. A television camera with a wide-angle lens directed at the workspace/living area and driving area permitted visual monitoring of the subjects. A lens cap was provided to the subjects to permit privacy when desired.

Both subjects wore two FM transmitters with pickup electrodes for continuous telemetry of heart and respiratory rate throughout each day and removed them before going to sleep. Each transmitter weighed approximately 18 grams with case dimensions of 32 x 25 x 16 millimeters. The E & M Instrument Company transmitters permitted short-range transmission of heart and respiratory rate with a maximum range under laboratory conditions of up to 100 feet. Light-weight silver-disc self-adhering electrodes were used with E & M electrode paste.

2.1.3 Pressure Suits and Portable Life Support System (PLSS)

Each subject had two current, functional pressure suits provided by the NASA Crew Systems Division, Manned Spacecraft Center, Houston, Texas. Throughout most of the simulation the subjects used Apollo state-of-the-art suits. HECMAR suits were used as backup equipment. The suits required on-the-spot repairs and suit replacements in several instances. Four Portable Life Support Systems (PLSS) were simulated by wooden mockups of representative weight and volume. Suit pressurization was regulated by the subjects, a pressure of 3.5 psi being maintained during inflated tasks by the operation of a small regulator attached to the backpack and accessible to the subjects during pressure suit activities. All outside tasks were performed in the inflated pressure suits. A flow rate of approximately 0.34 cubic meters (12 cubic feet) per minute was maintained using banks of compressed air tanks and appropriate regulators. The inlet suit air was cooled by passage through copper coils immersed in a cold liquid solution. Initially this solution consisted of alcohol and dry ice. This, however, cooled the air excessively resulting in inlet air temperatures lower than 0.5°C (30°F), capable of causing localized skin freezing without subject awareness. This problem was solved by using an ice water mixture which provided a constant suit inlet temperature of 12.2°C (54°F).

2.2 SUPPORT EQUIPMENT EXTERNAL TO THE SIMULATOR

The equipment used to generate the tasks was set up outside the simulator. This equipment is described in the "Description of Tasks and Physiological Measures" subsection (2.4). The experimenters' task equipment and recording stations are shown in Figures 1 and 19. Figure 20 shows the typical visual access gained through use of the TV monitor. A small treadmill with remote speed and grade controls was outside the vehicle for use by the subjects when performing simulated outside tasks (Figure 21). The treadmill could provide continuous speeds from 1.6 - 16 Kmph (1 to 10 mph) and grades from 2 to 40 percent. The interrelationship of these various components with those inside the simulator are indicated in Figure 22.

2.3 SUBJECTS

Two experienced engineer-scientists from the NASA Marshall Space Flight Center served as subjects. They were Mr. Michael J. Vaccaro, designated as Commander during the simulation and hereafter referred to as Operator 1 and Mr. Haydon Y. Grubbs, Co-Commander, hereafter referred to as Operator 2. Both men are vitally active in studies associated with lunar surface missions and were highly motivated test subjects. Operator 2 was a senior pilot with approximately 1000 hours of jet flying time. Both men were experienced in simulation studies and in the background and purpose of this particular lunar surface vehicle simulation. Each subject has had extensive experience in the use of various NASA pressure suits and their support equipment. The subjects' physical dimensions are given in Table 4.

2.4 DESCRIPTION OF TASKS AND PHYSIOLOGICAL MEASURES

2.4.1 Task Descriptions

The following tasks were performed:

2.4.1.1 Task Involving Statistical Design Requiring Controlled Presentations -- These tasks were analyzed by simple statistics and graphical trend analysis. The data were stored on punched cards. Means, standard deviations and tables were generated by computer on a daily basis for both subjects combined and for the individual subjects. (Appendix III describes the analysis procedure.)

2.4.1.1.1 Driving Tasks -- The driving task was a pursuit tracking problem displayed on a dual-beam oscilloscope. The display presented two spaced vertical lines, representing a "road path," which oscillated horizontally as they were driven by three sine-wave function generators in parallel. (A schematic of the driving task is shown in Figure 23).

The subject controlled a small dot on the scope by means of side-to-side motions of a modified developmental Apollo side stick control having 2 degrees of freedom in a single axis. The subject's task was to keep the dot centered on the simulated "path". Subject errors were recorded by an analog computer as the absolute integral error resulting when the dot was outside the roadway. Total integral error was also displayed on a Sanborn recorder. Based on pre-simulation evaluations, three error categories were derived relating the integral error to location on the navigation map (Table 5). Subject time-off-course was recorded directly by means of a clock timer. Each driving task consisted of eight 5-minute presentations. Two frequencies were displayed to the subject (Figures 24 and 25), the order of their presentation during eight driving subtasks being systematically varied.

2.4.1.1.2 Monitoring Tasks -- While one operator was driving, the other operator performed monitoring tasks. These tasks consisted of: (a) monitoring the driver's time "off course" by responding to a push button which was lighted whenever the driver left the "road way" and (b) an associated change-no-change pattern recognition problem. The latter problem presented various light patterns on a nine-light panel, the operator being required to scan the pattern for a "change" or "no-change", and then make the appropriate push-button response. This task represented monitoring of vehicle subsystems.

Two monitoring tasks were time-shared. Off-course time monitoring error, Δt, was recorded as the difference between the time the monitor's switch was depressed, t_m, and the time the driver was off course, t_o, per five minute driving task:

$$\Delta t = t_m - t_o$$

This particular recorded parameter warrants a brief description of the procedure used in handling the data for this task. Δt has a finite lower limit due to the monitor's reaction time. Thus t_m is always greater than t_o provided the monitor does not release the switch while the driver is still off-course; t_o has a maximum upper limit of 300 seconds for the worst possible driving condition (i.e., if the driver should be off course the full 5-minute driving period). To account for variations in driving proficiencies, the monitoring error was considered as a percentage:

$$\text{Percentage of off-course time} = \frac{\Delta t}{t_o} 100.$$

Considered in this manner, it is obvious that a 100 percent monitoring error means that the monitor switch was depressed twice as long as the time the driver was off course, that is if:

$$\frac{\Delta t}{t_o} = \frac{t_m - t_o}{t_o} = 1, \quad \text{then } t_m = 2t_o$$

Since t_o has a possible lower limit of zero (the driver never being off course), the ratio $\frac{\Delta t}{t_o}$ approaches infinity for the perfect driving condition for any finite monitoring time, t_m.

These conditions were observed in the data as is noted in the results subsection for this task.

2.4.1.1.3 Navigation Task -- The subjects were provided with maps of the intended lunar traverse for the 14-to 21-day mission (Figure 26). As the mission progressed, the subjects' position was determined by the experimenters as a function of driving task performance. The experimenters kept track of the vehicle on a large master map (Figure 59). The position of the vehicle in relation to various map features was determined by the experimenters in terms of lines-of-bearing. Simple triangular objects representing the lunar terrain features were mounted at the appropriate angles on the rim of a large disc mounted on the top of the LUNEX II simulator (Figure 27). The subjects then performed a navigation task to determine their position. The navigation task was a time-shared task. The subjects initiated the task by starting a timer and indicated task completion by switching the timer off. A war surplus panoramic periscope had to be mounted through the ceiling in the center of the disc to perform the sightings and stowed at the completion of each sighting task. The subjects' task was to set up the periscope and determine the angles to the appropriate terrain features. The accuracy of the subjects' angular measurements were evaluated. Based on these angular measurements, the subjects "fixed" their location and transmitted their position in map reference coordinates to the experimenters. The "charting error" was the difference between their determined location and the actual location.

2.4.1.1.4 Audio Balancing -- To observe the subjects' response to stimuli other than visual andtactile, the subjects were required to balance a Wheatstone bridge to four-decimal-place accuracy by audio means. This task simulates a physical chemical procedure commonly used to determine the ionic resistivity of unknown solutions (in this case, an imaginary lunar dust sample in solution) by comparing the sample resistivity with known standards.

A stereo headset connected to two variable-audio-frequency generators (one earphone to each generator) was used by the subject to compare and match two audio stimuli. (The functional schematic for this task is shown in Figure 31). Digital counters were used for accurate frequency recording. The frequencies presented to the subject were selected from a range of 800 to 1000 cps, divided into 10 approximately equivalent intervals. Each frequency was presented at an intensity of 70 db once per experiment in a randomized order.

2.4.1.1.5 Sample Measurement -- Precise scientific work can be expected of astronauts on a lunar mission. To simulate such precise work, the subjects were required to measure the outside diameter of optically calibrated aluminum discs, using a traveling microscope. The accuracy and time of the measurement was recorded. Accuracy to four decimal places was required of the subjects.

2.4.1.2 Tasks Providing Mission Realism and Basic Behavioral Measurements --

2.4.1.2.1 Geophysical Tasks -- The University of Minnesota Geophysics Department provided a variety of tasks designed to represent the type of geological activity expected on early lunar missions. These tasks were not intended to imitate actual lunar mission tasks but to represent simple yet realistic geological activities. The tasks required the collection of as many different rock and mineral categories as possible, retaining only one sample of each category. The tasks further required that the traverse of the lunar mission be accurately mapped with respect to prominent known terrain features and that new terrain features be mapped as they are observed. The careful collection of rock and mineral samples such that the scientific value of the return payload is maximized while minimizing its weight involves both macroscopic and microscopic analysis. The macroscopic analysis began with the subject in the inflated suit making judicious rock sample collections during his extra-vehicular activity. Nearly 100 rock samples, representative of the types geologists expect to find on the moon, were located in the area outside the LUNEX II simulator (Figure 29). The subjects' task was to visually sort the samples and select 20 rocks appearing to represent discrete categories. These 20 samples were returned to the LUNEX II where analysis of the samples was performed. In each of the 20 samples, there was no more than eight categories. The subject's task was to determine which eight should be returned to earth (Figures 30 and 33). Microscopic analysis of mineral samples required the analysis of mineral grains by use of a binocular microscope and a polarizing microscope (Figures 31 and 32). Mineral crystals requiring sorting by category and by properties were provided. These crystals had to be identified by sampling and microscopic counting. The minerals mounted on petrographic slides required analysis by the determination of anisotropic, isotropic and opaque light transferring properties using the polarizing microscope. The subject's task was to sort crystals and to distinguish distinct mineral samples mounted on petrographic slides. These tasks are shown in Figures 34 and 35 respectively.

In association with the navigation tasks, specific terrain features were revealed at irregular times and had to be located on the subjects' map. For example, a particular mountain was shown during one navigation period. The angle to the mountain was noted and a ray drawn from the LUNEX II location through the mountain location. After several driving periods, the same mountain was again shown and a ray drawn. The intersection of the rays located the new terrain feature on the subjects' map. In this way, single-dimension plotting of simulated lunar terrain features was possible.

2.4.1.2.2. Skill Retention Task -- This task was associated with the pattern recognition monitoring task previously described. During the presimulation training period, specific patterns were presented on the nine-light panel. The subjects were required to respond in a different manner to each pattern. These selected patterns were presented only sporadically throughout the simulation. The subjects were scored according to their retention of the particular response sequence.

The skill retention task was designed with three primary goals. These were to measure the degree to which pattern recognition deteriorated during the simulation, to detect changes in visual-motor skill retention as a function of practice, and to add interest and variety to the monitoring task.

This task used the same nine lights and three buttons as the change-no-change pattern recognition task and was interspersed with it during the monitoring periods each day. During the practice sessions, the operators learned the correct response to each of seven pairs of light patterns. Each pattern consisted of five lights, and the same pattern in two rotations was used in each pair (see Figure 36). The driving and monitoring periods were divided into 5-minute segments. On the average, one pattern would appear on the nine-light matrix during each segment. At this point, the monitor had to realize that the pattern recognition task was no longer running.

This was possible because five lights, instead of the usual four, three, two, or one, were lighted. He then had to push the correct combination of buttons which would turn the pattern off and cause the regular task to resume. Reaction time, total time to achieve a correct response, and number of buttons pushed were recorded automatically during this period on a four-channel Sanborn recorder. Some patterns were presented more often than others so that practice effects could be measured. Figure 37 shows the frequency of presentation of each pattern for both operators. The plan was to have three of the pattern-pairs presented every day and to space the presentations of the other four to give data points for many practice conditions. Because monitoring periods were often irregular, the original schedule of presentations was not closely followed. This, however, did not seriously affect the analysis of the data.

2.4.1.2.3 Gimbal Position Indicator Task -- This task required precise settings of yaw, pitch and roll gimbal positions on a flightworthy piece of Apollo hardware. The task was conceived in cooperation with the Honeywell Apollo group which has the responsibility of designing and furnishing the Stabilization and Control System for the Apollo Command Module. The task required precise inputs to be set into the Gimbal Position Indicator in the shirt-sleeve, ventilated and inflated suit conditions. The task simulated putting information into an on-board lunar surface vehicle computer. It also provided meaningful data to the Apollo Group regarding the accuracy of settings in various suited conditions. The principal comparison desired was between setting accuracy in the shirt-sleeve condition and in the ventilated suit condition. For these conditions, each subject performed in both the shirt-sleeve and ventilated suit condition, on the same day.

2.4.1.2.6 Emergency Tasks -- Emergency tasks requiring the use of the pressurized suit were introduced sporadically into the simulation mission activities. These tasks involved: (a) emergency rescue of an "injured" operator outside the vehicle, and (b) emergency operation of cabin systems during simulated cabin or airlock pressure failures. In addition, the effect of a temporary disability of one operator was examined.

2.4.1.2.7 Subjective Data -- The subjects were required to make subjective evaluations of the simulation after the completion of 3 days, 7 days and 14 days in the simulation. Modified Cooper Scale evaluation forms were used to obtain numerical ratings as well as written comments (Figure 38). Similar forms were also completed for each emergency task. These forms were completed independently by each subject.

In addition to the evaluation forms, each subject kept a detailed daily log which was available to theexperimenters upon completion of the simulation.

2.4.2 Physiological Measures

In addition to evaluating crew performance by integrated behavioral and psychophysiological tasks, selected physiological factors were evaluated. The maximum oxygen consumption measurements (obtained by requiring the subjects to work on a treadmill during indirect calorimetry) were performed by the University of Minnesota Laboratory of Physiological Hygiene. These formed the basis for evaluating relative task workloads using calibration curves relating oxygen consumption to heart rate and respiratory rate derived for each subject during the presimulation period. Heart rate and respiratory rate were monitored continuously during the day using a two-lead telemetry system and a polygraph. Sample traces are shown in Figure 39. Mean heart and respiratory rates were obtained during performance of tasks. These rates, when considered as a percent of each subject's maximum steady-state rate obtained during maximum oxygen determinations, permit comparison of relative task workloads (Ref. 4). A measurement of each subject's maximum oxygen consumption immediately after the simulation provided a direct evaluation of physical fitness changes in the subjects during the simulation. Urine samples were analyzed for 17-ketosteroids and 17-hydroxycorticosterone (cortisol) as well as for glucose, ketones, pH and protein. Body weight and food and water consumption were recorded throughout the experiment as well as urine volumes and the wet and dry weight of the feces.

The temperature of the simulator cabin as well as the intake and output temperatures of suits when worn were also monitored.

2.5 SIMULATION TIME LINES

The initial crew time line was derived from previous studies (Ref. 1) and from examining MOLAB time lines generated in related studies (Refs. 13 and 18). The simulation activities were initially guided by the 24-hour repeating activity sequence shown in Figure 40. The subjects alternated between sequence A and B on a daily basis. These activities fully occupied a 16-hour work day. As the simulation progressed, this activity sequence evolved to an operational time line with experimentally determined task activity time constraints. Based on this evolution and on the mission goals to accomplish maximal scientific exploration and optimal and efficient scientific analysis and sample collection, a functional simulation time line was established. The meals and sleep periods were held constant through the simulation.

2.6 PRESIMULATION CHECKOUT PERIOD

Prior to the initiation of the simulation, the NASA-furnished subjects completed an intensive five-day presimulation checkout. This checkout involved anthropometric measurements, training in the simulation tasks and the determination of their maximal oxygen consumption and the associated heart and respiratory rates. The subjects began the simulation anticipating a 14-to 21-day mission. They did not know the exact length of the simulation. This knowledge was withheld to avoid the goal-gradient effects of increased excitement and anticipation as the completion day drew near.

SECTION 3
RESULTS

3.1 TASKS

3.1.1 Driving Task

The average of the subjects' driving errors and tracking off-times for both displayed frequencies (speeds) are shown in Figure 41 as a function of time in the simulator. Driving errors and their standard deviations for both subjects at speeds 1 and 2 (Figures 42 and 43) were generally independent of displayed frequency (speed) of the tracking tasks. Tracking off-course time was also largely unaffected by the speeds displayed (Figures 44 and 45). Tracking remained generally uniform throughout the simulation, tending to become better with time, with the exception of day 14 where an appreciable worsening in performance occurred. Driving performance was more erratic after day 13. A comparison of the subjects' driving performance shows the same trend for both subjects (Figures 46 and 47). Though both subjects showed a performance decrement on day 14, Operator 2 did not show a performance decrement on day 17 as did Operator 1. (Graphs and standard deviations of each subject's driving error and tracking off-course times for each speed are given in Appendix I.) The worsening of performance on day 14 is believed to be caused by the subject's anticipation of this significant milestone day. According to the subjects, this anticipation was appreciable as reported in post-simulation debriefings. Support for this belief independent of the subjects' opinions will be evident in discussing the navigation task results. Operator 2's generally better performance is attributable to his experience in flying aircraft. Of most significance is the fact that both subjects maintained consistent and improving task performance for 14 days and did not show serious performance decrements throughout the entire 18 days. This performance occurred despite the fact that several equipment problems interrupted the driving task. In addition, the modified Apollo control had an electrical and mechanical dead spot at its null point which annoyed the subjects to the extent that they removed all springs from the control the evening of the 12th day in the simulation. This alteration did not, however, affect performance (Figure 41); the next day's driving performance was nearly identical to that preceding the control alteration. (It should be noted that all driving task equipment with the exception of the control stick was external to the simulator, the display being viewed through a shutter apparatus that could be closed for display removal. Electronic equipment repair was performed without disturbing the subjects.)

3.1.2 Monitoring Tasks

3.1.2.1 Driver's Off-Course Time Monitoring -- Figures 48 through 52 present the average precentage error $\left(\frac{\Delta t}{t_o} 100\right)$ for both subjects at different driving speeds. Operator 1's monitoring tended to improve with time up until about day 12 (Figures 49 and 50) in general accordance with Operator 2's driving off-course time. Operator 2's monitoring performance was more erratic and did not show any pronounced trend (Figures 51 and 52). The apparent worsening trend in Operator 1's performance after day 12 is attributable to the treatment of his error as a percentage of the time the driver was off course and not to Operator 1's actual performance. Operator 2 tended to consistently reduce his off-course driving times (t_o), with the result that Operator 1's average percentage off-course monitoring $\left(\frac{\Delta t}{t_o} 100\right)$ became relatively larger. This effect is appreciable only for Operator 1 and then only for the last four days of the simulation and is greatly exaggerated on day 18. On day 18 Operator 2's driving off-time, t_o, became very small (see Figures I-11 and I-14 in Appendix I) resulting in $\Delta t/t_o$ becoming large even though Operator 1's Δt averaged only 0.3 second for speed 1 and 0.4 second for speed 2 per five-minute driving period (see Table 6). Figure 53 presents a plot of the monitoring error (Δt) in seconds versus days in the simulator. This plot clearly illustrates that no adverse trend exists in monitoring and that the monitoring error, Δt, very closely follows the driver's off-course time (e.g., compare Figure 53 with Figures 44 and 45). Monitoring error was not appreciably affected by driving speed.

The off-course time monitoring task is a routine task tending to be boring. The often large and erratic standard deviation appears to reflect this (see Figure 52 for example). Of most significance is the fact that the subjects conscientiously and satisfactorily performed the task throughout the simulation.

3.1.2.2 Change-No-Change Light Pattern Monitoring -- The responses to the change-no-change pattern monitoring task are shown in Table 7 and depicted graphically in Figure 54. Increasing trial numbers correspond to increasing time in the simulator. Due to equipment problems, the results through the first 24 trials can be evaluated only in the most general terms. The last three trials do, however, represent reliable data points and as such lend credence to the earlier trial results. Both subjects consistently performed this monitoring task with 86 to 100 percent accuracy.

3.1.2.3 Skill Retention/Pattern Recognition Task -- Times and errors for each presentation of each pattern are presented in Tables I-1 and I-2 in Appendix I. Blank columns in these tables represent days on which no monitoring tasks occurred for that operator. Days are numbered starting with day 2, Monday, February 21.

Figures 55 and 56 show the trends in response times and errors over days. There were no significant trends after the first four days, when both time and error scores dropped. This initial drop is probably due to practice effects. On day 11 Operator 1 changed his method of responding to patterns. He would keep trying different button combinations until one worked. A decrement in time and error scores on that day reflects this change. On the following day, Operator 1 was back to normal. The rise in time and error scores on the last two days is the only change which could be attributed to the simulation routine. This rise probably reflects a growing impatience on the part of the operators which might not be present on a real mission where the date of the end of the mission is not as uncertain.

Figure 57 is a scatter-plot of the number of times each pattern was presented and time to correct response for that pattern, for both operators. The correlation between these two measures, -0.54,is not high, but it is a significant one. Onthe whole, the less often a pattern was seen the longer it took to give a correct response.

Pattern recognition of the kind used in this task is not an easy job. The operator had to remember seven different responses to 14 different patterns, on some of which he had very little practice during the simulation. In addition, it was hard to develop a simple response set to the onset of a pattern, since these patterns differed from the ones continually occurring during the monitoring task only in having one more light lighted. Also, the operator was instructed to keep pushing the driving-monitoring button while responding to the pattern. Considering these complications, the commonly occuring response times of 1 to 2 seconds with zero errors demonstrate a high degree of skill, skill retention and attention in both operators. This level of performance was maintained throughout the simulation with remarkable consistency. Malfunctions of the programming equipment caused the operator to express frustration, but this was not reflected in the performance scores.

3.1.3 Navigation Task

3.1.3.1 General -- Due to the high angular resolution of the periscope, angular sightings having an average daily error greater than the accuracy of placing the simulated lunar mountains (±0.5 degree) occurred only twice during the simulation, on days 17 and 18. The average time to complete the sighting task is shown in Figure 58. The average charting error in plotting their locations is shown in Figure 59. The subjects performed the task progressively faster through day 10 (gaps in the data occurred because navigation was performed only when driving tasks were accomplished). Within the experimenter's accuracy, the subjects performed this task very well, though charting errors were more erratic after day 10. Figure 60 is a reduced drawing of the experimenter's master maps. The subjects sighted on the mountains marked by an X to obtain a "fix" of their position. The initial time line had called for three navigation tasks per day. The map of an approximately 200-mile lunar traverse was constructed on this basis. The evolving time line generated during the simulation resulted in only two navigation tasks per day. This fact together with driving task equipment failures resulted in the subjects' progress on the traverse being considerably slower than anticipated. As a result, the LUNEX II was nearing the crossover point with the mission origin (where an imaginary LEM was parked) on day 14. This fact is believed to have contributed to the subjects' probable expectation that the mission would terminate on day 14. The actual traverse covered by the LUNEX is described by the set of ordered points 1, 2, 3, 4, 5, 6, 7, 8, 9, 14, 16, 19, origin - as shown in Figure 60. A reproduction of the subjects' map with its calculations is shown in Figure 61. A comparison of this map with that shown in Figure 26 indicates the effort expended on this task.

3.1.3.2 <u>Single-Dimension Plotting of Simulated Lunar Terrain Features</u> -- The location of the 13 lunar terrain features presented periodically to the subjects during the navigation task are indicated on the experimenter's map of Figure 60 (those not marked with an X). The actual location of these peaks is indicated by the points at which the rays (dashed lines) intersect. The subjects' location of these peaks is indicated by the dotted circle. These 13 peaks were generally located satisfactorily. This task was not scored but did prove of considerable interest to the subjects. (The time to perform this task was not included in the time to navigate and find vehicle location.) The subjects' actual rays as drawn during the simulation are shown in Figure 61.

3.1.4 Audio Balancing

The results for this task are shown averaged over both subjects in Figures 62, 63, and 64. Differences between the subjects were small, although Operator 2 was generally better at matching frequencies than Operator 1. The frequency-matching errors and time were not remarkable throughout the simulations, no effects due to stay in the simulator being observable. Days 6, 7, and 15, however, show an increase in error with large standard deviations (Figure 64). The cause is not known.

3.1.5 Sample Measurement

The results of the sample measurement task are shown in Figures 65 and 66. The subjects were able to decrease their measurement times without affecting their accuracy during the simulation. The subjects were able to measure the discs to an accuracy better than 0.0020 centimeter (0.0008 inch) throughout most of the simulation. This task clearly illustrates the ability of motivated subjects to consistently perform a high-accuracy task during an extended lunar surface simulation.

3.1.6 GPI Task Results

The results of this task will be presented at a later time in a Honeywell Apollo Systems report.

3.1.7 Comparison Between Subjects

Comparisons have been made between subjects in the preceding task results. A comparison of subject performance on these tasks over the simulation is shown in Table 8. In the light of Operator 2's pilot experience and possible age difference effects, subject differences are not noteworthy with the exception of the driver's off-course time monitoring task.

3.1.8 Geophysical Tasks

During the presimulation period, the subjects were given a two-hour introduction to the geophysical problems and their associated equipment. Operator 2's background included a geology course during college. Operator 1 had no prior exposure to geology or its methods.

3.1.8.1 Rock Sample Analysis* -- A summary of the results is given in Table 9. The results shown are based on an evaluation of the rock samples over the entire mission. Two analyses of the rock samples were performed, one being completed in the mid-portion of the simulation, the other in the latter phase. The second analysis did not contain the gross error cited in Table 9. The principal result of this task is to indicate that men with very little geological training can, with the proper choice of elementary equipment, discriminate between varieties of rock in a judicious manner such that only one sample of each variety may be returned to earth.

3.1.8.2 Mineral Point Count Task -- This was a painstaking, time-consuming task requiring the subjects to sample carefully from a heterogeneous mixture of tiny mineral grains and then to sort and count using a binocular microscope. The subjects did not have enough time to perform the task to their satisfaction. They did, however, count over 1000 mineral grains in a total of seven samplings from the mixture provided. Each of the three mineral categories were subdivided into the three mesh sizes. The subjects did not have time during the simulation to convert their data into the final percentage form required. This data was converted by the experimenter with the results shown in Table 10 together with the actual percentages. Though there are obvious differences between the experimental and the actual percentages that exceed the differences implicit in weight-versus-number percentages, there was sufficient uniformity to permit the subjects to make meaningful conclusions about their unknown sample mixture. For example, there were equivalent percentages of medium grains in all minerals present; likewise, there were more small quartz minerals then any other species, and there were comparable amounts of small pyrite and

*This task was designed and graded by Dr. G. Rapp, University of Minnesota.

pyroxene minerals. These results indicate that detailed analyses of geological samples are possible in a lunar surface vehicle. Both subjects felt, however, that a task of this type is too time consuming for an actual mission and that rapid analysis techniques or retrieval for earth analysis of the entire surface sample would be better.

3.1.8.3 Petrographic Slide Analysis -- This task was performed very well by both subjects. This fact is especially impressive since neither subject had previously used a polarizing microscope. The correct answers for the analysis are shown in Figure 67 to indicate to the reader the type of response required. The subjects were scored on the basis of 10 total points, a half point each for the decision to collect or not collect the sample and a half point (or appropriate fraction of point) for the analysis of the slides components. The subjects each performed two analyses of the 10 slides during the simulation period. Operator 1 got 60 percent right on his first analysis and 80 percent right on his second analysis. Operator 2 got 83 percent right on his first analysis and 85 percent right on his second analysis. A task of this sort could easily be accomplished on a lunar mission if the appropriate rock crushing equipment were available. Mounting unknown mineral samples on petrographic slides and analyzing them with a polarizing microscope permits the collection of distinct rock samples with maximized information and minimum return payload weight. As with the other geophysical tasks, this task can be accomplished with little geological training.

3.1.9 Minnesota Multiphasics Personality Inventory*

The subjects were given the Minnesota Multiphasic Personality Inventory* (MMPI) during their first day in the simulator and again on the 18th day. The

*Mr. Floyd Ayers, psychologist of the American Rehabilitation Foundation, Minneapolis, kindly consented to analyze the Minnesota Multiphasic Personality Inventory administered to our subjects.

profile for both subjects on each of the two testings were well within normal limits. The profiles are shown in Figures 68 through 71.

A complete test evaluation is included in Appendix IV. Due to the personal nature of this test, this appendix is published as a separate document and is available for limited distribution through the office of Dr. Stanley Deutsch, OART, Washington, D.C.

3.2 EXTRAVEHICULAR ACTIVITIES

The subjects were permitted to exit from the LUNEX II approximately once a day per subject for 30 minutes to one hour. This activity was always performed in inflated (3.5 psi) pressure suits. The operator preparing to exit donned his suit in the airlock without assistance. The operator remaining inside assisted the exiting operator with his PLSS donning. The operator remaining inside donned his suit in the cabin and remained in the vented suit condition during the other operator's outside activity. The exiting operator was required to wait 5 minutes after pressurizing and securing the inner airlock door while a simulated airlock pump-down cycle took place. The airlock volume and ceiling height were found to be completely satisfactory for this. However, during the simulation the subjects installed hand holds in the airlock to assist them in donning and doffing the suit and maintaining position during airlock pump-down and pump-up. Efficient inflated pressure suit activity is contingent (in the suits used) on proper adjustments of all straps -- the adjustment for the standing position being different from that for a crouched or sitting position. In an airlock prohibiting standing erect, it was found to be highly desirable to have all pressure suit straps pre-set for an erect standing position.

The subjects took a sample carrying bag and large leather mittens with them as they exited the vehicle. The pressurized Apollo state-of-the-art gloves were easily punctured by the sharp rock samples to be retrieved, making protective mittens necessary. Treadmill activity in pressurized suits was found to be sensitive to subject experience (experience on treadmills in the shirt-sleeve condition did not appear to transfer significantly to the inflated suit condition), on the particular pressure suit worn and on the suit temperature. Physiological effects and adaptation to working on the treadmill in pressurized suits is discussed in the Physiological Measures Results Subsection (3. 4). For inflated suit work it was found that a treadmill belt wider than 61 centimeters (24 inches) is desirable. The subjects enjoyed the treadmill exercise and looked forward to it. Neither subject experienced difficulty in performing the task. Both progressively improved in their ability to do work on the treadmill.

3. 3 EMERGENCY STUDIES

Emergencies can be expected and must be anticipated in any lunar surface mission. In the present simulation, possible emergencies could not be systematically examined in detail without a major disruption of the simulation. It was possible, however, to perform four simulated emergencies plus a procedural examination of the effect of temporary disability of one operator. The principal objective of these emergencies was to evaluate the vehicle volumes during various emergency activities.

3. 3. 1 Rescue of "Injured" Operator

During one of the subject's extravehicular activities the other subject was told that the outside operator was in serious danger requiring immediate rescue. In the meantime, an inflated Arrowhead Mark II suit with a backpack was substituted for the outside operator - the outside operator being permitted to depressurize and retire to an isolated area immediately outside the LUNEX II and the rescue area. Verbal and visual contact with the operator "standing by" during the rescue was minimized. The weight of the inflated Mark II suit and backpack was about 23 kilograms (50 pounds), approximately the weight of a similarly suited astronaut on the moon. The inside operator's task was to don his suit and backpack, pressurize, drop cabin "pressure" (the airlock being "depressurized") and proceed with the rescue tow line to the injured operator. A power winch was controlled by the experimenter on the command (via the communication system) of the operator performing the rescue. The first rescue was performed by Operator 2 on the second day of the simulation. The results pertinent to this rescue indicated the following:

- Power assistance is mandatory for this type of rescue.
- With power assistance, Operator 2 was able to rescue the "downed operator" and successfully secure both himself and the inert "operator" in the airlock.
- A means of restoring cabin pressure from the airlock should be installed to permit the returning operators to enter the main cabin area as soon as possible after the rescue is complete.
- The task is physically strenuous as reported by the subject and as indicated by his heart and respiratory rates (Figure 72).
- Operator 2 rated the task as "acceptable for emergency conditions only", a numerical rating of 3 on the modified Cooper scale (this scale is shown in Figure 38).
- Approximately 30 minutes were required to effect the rescue.
- Assistance was needed in getting the backpack on.

Operator 2 used the procedure found necessary in previous studies (Ref. 1) to place a recumbent pressurized operator in the "spread eagle" position in the airlock; i.e., the recumbent operator is put in the airlock head first in a face down position, resulting in his chest facing the inner bulkhead. The operator performing the rescue then follows, securing the outer airlock door behind him.

Operator 1 performed the emergency rescue on the 15th day of the simulation. The rescue was in every respect similar to test performed by Operator 2 up to the insertion of the "injured operator" into the airlock. Operator 1 was instructed to place the "injured operator" in the airlock according to a procedure that was found inadequate in previous studies (Ref. 1). In this procedure the rescuer backs into the airlock pulling the injured man in so that his backpack faces the inner bulkhead. This was found to be unworkable in the 1.31 cubic meters (47-cubic-foot) airlock previously studied but it was believed that the present airlock - having a volume of 1.86 cubic meters (65.9 cubic feet) in the emergency condition - might allow this procedure to be followed. The results showed this belief to be in error. Operator 1 succeeded in getting the "injured operator" partially into the airlock - the "injured operator's" legs projecting from the airlock. In attempting to step over the injured operator to improve his position, the "injured operator" fell against Operator 1 pinning him against the wall where his backpack wedged. Operator 1 was rendered immobile and had to depressurize to get up. Operator 1 rated the task "acceptable for emergency only".

The significant findings of these simulations are:

- It is necessary to have well worked out procedures for getting two pressurized operators, one being incapacitated, into a small-volume airlock.
- The airlock will contain two pressurized operators - one being totally immobilized.

- Power assistance is necessary.

- Further study of emergency rescue procedures, examining various mechanical aides and alternative airlock geometries is required.

3.3.2 Emergency Loss of Cabin Pressure, Airlock Pressure System Remaining Operative

Both operators were unexpectedly aroused from their mid-day rest period on the 11th day by a warning horn. They were told that cabin pressure was slowly falling due to a meteorite impact. They were to proceed immediately to the airlock where they would don their suits and backpacks, pressurize together, drop airlock pressure and exit the LUNEX II to make emergency repairs, (the repair was simulated by removing adhesive patches affixed to the outside surface of the vehicle). While they were outside the vehicle they were informed via the communication system that the lunar surface crust was giving way under the LUNEX II and that they must immediately re-enter the vehicle, and, without repressurizing the cabin, drive the LUNEX II to a safe location. The subjects entered, doffed their backpacks and maintained suit pressure on the cabin system, which was assumed undamaged, leaving their backpacks in the air-lock. Simulated cabin pressure was then restored and the emergency was terminated. Total time for the emergency was somewhat over 2.4 hours. This simulation had the following results:

- The airlock volume was sufficient for the two crew members to don suits and backpacks and simultaneously inflate their Apollo state-of-the-art suits.

- The inner airlock hatch is not large enough to permit access of a pressurized man with the backpack on but permitted passage of the operators in inflated pressure suits.

- Though the driver's hand control position was less than optimal in the inflated suit condition, both driving and monitoring tasks could be successfully accomplished, driving error for Operator 2 being approximately one standard deviation larger than in the average shirt sleeve condition.

- Cabin volumes, driving station volumes, and chair locations were adequate for inflated pressure suit use. However, one of the adjustable lights in the cabin was broken by the helmet of Operator 1, suggesting that all light fixtures be recessed or guarded.

- Hand holds were recommended (and later installed) on the upper side of the wall adjacent to each chair to facilitate ingress and egress from the chairs while in the inflated suits.

- All equipment must be kept stowed in its proper place at all times to avoid unnecessary delays during emergencies.

- The suits and their associated equipment must be kept in a constant state of readiness in the event of an emergency.

- Excessive physical exertion was not required by the subjects during this emergency as evidenced by heart rates (Figure 73).

- Both operators rated the task "acceptable for emergency conditions", number 3 on the Cooper scale.

3.3.3 Emergency Loss of Airlock Pressure with the Cabin Pressure System in Jeopardy

The emergency was simulated on the 16th day. The subjects were told that the airlock had been punctured by a jagged rock, resulting in a fairly rapid pressure loss and putting the cabin pressurization system in jeopardy. The operators' task was to secure the inner airlock door, don suits in the cabin using their backpack air supply rather than the cabin air supply, and drive the vehicle to a smooth area for repair. Both operators were then to egress from the vehicle and proceed to "repair" the vehicle. They were then to re-enter the vehicle, securing both hatches after them. Each operator was then requested to perform the Gimbal Position Indicator Task, drive and monitor once more, and then depressurize on the assumption that both cabin and air-lock pressure were restored. The object of this simulation was to get as much simultaneous interaction of the two subjects with the simulator's restricted volume and geometry as possible while in the inflated suit condition requiring the use of the PLSS. The emergency lasted 1.75 hours. The principal results were:

- Both men could simultaneously don their pressure suits and inflate them in the cabin. The subjects independently rated this task as "satisfactory", a number 6 rating, on the modified Cooper scale.

- Driving and monitoring while pressurized by the PLSS is very difficult. The short PLSS hoses greatly restricted the operator's mobility. The encumbrance resulting from carrying the backpack with one hand while trying to ingress or egress from the chairs was severe. Specific suggestions made by the subjects were:

  - The backpacks should be stored immediately behind the seats to permit hookup to them while seated

  - It should be possible to wear the backpacks while seated or the hoses should be long enough to place the backpacks on the floor without being encumbered by them or their hoses.

  - The backpack connecting hoses should be long enough to permit each operator to stand up without lifting the backpack.

  - Controls, displays and seats need to be designed with the pressurized suit in mind.

- Both subjects rated this task as acceptable for emergency condition only.

- Ingress and egress to or from the cabin in the inflated suit condition cannot be done with the backpack on and can only be accomplished marginally while carrying the backpacks. (Operator 2 rated this effort totally unacceptable and dangerous.) To permit passage with the backpack on, both the aisle and the inner airlock door need widening, the critical dimension being the depth from the chest to backpack back surface.

- The aisle provided insufficient space for Operator 2 to operate the Gimbal Position Indicator thumb wheels. Operator 1 could get into position and perform the task but with considerable difficulty. Operator 2 rated this task as "unacceptable even for emergency condition". Operator 1 rated the task "acceptable for emergency condition only".

- Excellent communication systems are necessary at all times but especially during emergencies. A critical communications failure prevented Mission Control from maintaining contact with Operator 2 during a suit failure which caused a sudden drop in suit pressure followed by a rapid rise and then decompression. The emphasis on good communications cannot be stressed too highly.

- Donning of the backpack outside the vehicle with both subjects pressurized can be accomplished with little difficulty.

3.3.4 Temporary Disability of One Crew Member

The possibility of one crew member being temporarily disabled by a minor illness which would not warrant returning to the Lunar Excursion Module was examined. Operator 1 was assumed ill, requiring temporary bed rest (no pressure suits were required for this activity). This irregular situation was maintained for approximately 7 hours on day 16 of the simulation. Two bed configurations were examined. Partial extension of the upper sliding bunk (Figure 74) permitted Operator 2 to walk through cabin but did not permit access to all task equipment. A satisfactory arrangement was to have the upper bunk fully extended with the disabled operator reclining on the bottom bunk (Figure 75). This permitted Operator 2 to use the upper bunk as a platform to crawl from one area to another and provided an area on which to perform tasks. Audio balancing, Gimbal Position Indicator settings, sample measurements, navigation, charting and driving were performed satisfactorily in this manner. Operator 2's performance of these tasks was not deleteriously affected. Both operators rated this emergency condition as "satisfactory" - number 6 on the modified Cooper scale.

3.4 PHYSIOLOGICAL MEASURES

3.4.1 Diet

During the 17 full days of the simulation (excluding the first and last half days), each subject consumed an average of 615 grams (dry weight) of food per day provided in the dehydrated food diet. This diet contains approximately 16.6 percent protein, 18.3 percent fat and 60.1 percent carbohydrate, about 5 percent being estimated as ash and bound water. (The diet shown in Figure 17 was not rigorously adhered to though accurate accounts were kept of daily variations.) Based on the physiological heat values for metabolic calculations* and an average consumption of 615 grams per day per man, this diet yields 2975 kilocalories per day per man. The subjects were put on the special diet two days prior to the

*One gram of protein yields 4.1 kilocalories, one gram of fat yields 9.3 kilocalories, and one gram of carbohydrate yields 4.1 kilocalories (Ref. 6, 7 and 24). It should be noted that these metabolic conversion figures vary somewhat according to the source. The Reference 32 conversion figure being somewhat lower than those cited here.

initiation of the simulation. In general, they found the food satisfactory. The average coefficients of apparent digestability* were 95 percent for both subjects, indicating efficient utilization of the diet. Specific preferences and criticisms are listed in the Subjective Evaluation subsection (3. 5). Through the first 11 days the subjects complained of being "constantly hungry". Toward the end of the simulation the subjects suggested fewer meals per day and, in fact, rejected meals. The specific fluctuations in weight, water balance and physiological measures related to these subjective observations are examined in the following subsections. The time to consume a meal averaged 42 minutes per meal. Daily fluctuations in meal consumption time are shown in Figure 76.

3. 4. 2 Water Balance

The subjects were permitted to drink as much water as desired. An average of 2. 15 liters of water per day was required to rehydrate the food provided. The average daily intake and output values are shown in Table 11. Daily fluctuations in water intake and urine and fecal water output are shown for each subject in Figures 77 through 82. The daily values given are those obtained from summations over a 24-hour period which masks the diurnal urine cycle commonly found (Ref. 6).

Examination of the figures reveals considerably larger oscillations in fecal and urine output in Operator 1. At least three factors are believed to contribute to oscillations in water intake and output in both subjects - Operator 1 apparently being more susceptible to these factors than Operator 2. After the simulation had been underway for 4 days, it became apparent that the subjects were competing with each other to determine who could deliver the largest urine sample

*The coefficient of apparent digestability was calculated by subtracting the dry weight of fecal excretion from the dietary dry weight intake and determining the percent of total intake absorbed (Ref. 10).

in a single void. An examination of the subject's log books indicated that at times a deliberate effort was made to control micturition (e.g., from one afternoon to the next morning) in order to deliver the largest sample. Though this effort was not generally detectable in the data, at least two observations are clearly due to this effort. On the 11th full day of the simulation, Operator 2 avoided micturition and delivered an exceptionally large single sample on the morning of day 12 (Figure 80) with consequently a relatively low urine output on day 11. A similar effect was noted for Operator 1 on days 16 and 17 with the urine output on day 16 being reduced (Figure 79).

The second complicating factor was due to the introduction of a small amount of alcoholic beverage (2 ounces per subject) on the 7th and 14th day of the simulation. This depressant was introduced to the subjects as a reward on these mission milestone days. No effects directly attributable to the alcohol were observed in the performance data, nor were significant adverse effects expected in the physiological data. A noticeable effect, however, was observed in Operator 1 following the alcoholic beverage administrated on day 14 of the simulation. The subject had large urine outputs and loose stool on the following day (Figures 79 and 81). Similar but less marked effects were noted in Operator 2 (Figures 80 and 82). At that time it was discovered that the subjects had somewhat loose stools after the administration on the 7th day but had not reported it. Figures 81 and 82 essentially present a time course of water lost chiefly as perspiration. On the days effected by the alcoholic dose notable decreases in perspiration rates occurred probably due to the body's effort to maintain water balance. The effect on urine output may be evident in both subjects following the 7th day (see day 8 of Figures 79 and 80). Operator 2 was noticeably less affected than Operator 1. The diuretic effect of the alcohol) was not as adverse as the tendency to cause diarrhea.

*The diuretic effect of alcohol is common knowledge; its diuretic action, however, is due to dosage irrespective of the volume of the dose. This effect is believed to be due to the inhibition of nerve centers controlling the release of the antidiuretic hormone (ADH). See Reference 6, p. 713.

The use of alcohol with space food diets (despite its beneficial use as a relaxant during non-critical activities (Ref. 6, p. 591) is not recommended unless used explicitly in the treatment of edema with hemodilution (Ref. 6, p. 713). Independent of the aforementioned factors, the data suggest (Figures 77 and 78) that water intake in excess of that required to rehydrate the food is responsive to the cyclic water requirements of the diet, water intake being pronounced during days when the diet calls for decreased water for rehydration. The effect of reducing the extremes of water intake cycling could possibly be achieved by having the diet require less oscillatory rehydration water. It should be noted that, with the exception of days 1 and 3 (on which neither subject performed extravehicular activities), the subjects were performing routine extravehicular tasks. It is not believed that water losses through perspiration biased water demands in any cyclic fashion.

3.4.3 Weight Exchanges

3.4.3.1 Body Weight Changes -- Both subjects admitted to being constantly hungry during most of the simulation. By day 14, however, their appetites had diminished to the extent that one meal was skipped. During the remainder of the simulation, food items were frequently rejected. Weight changes were seen to correspond to appetite changes during the simulation, the subjects either gaining (Operator 1) or holding a constant weight (Operator 2) until day 14, thereafter losing weight (Table 12). This is evident in the percent weight changes, the subjects' percent weight loss being 3.9 percent and 3 percent respectively from day 14 to day 18 (Figure 83). The reason for the weight reversal (or the corresponding food rejection) is not clearly understood. Water losses via perspiration were clearly evident to the subjects following inflated pressure suit activity on the treadmill. Increased perspiration rates are indicated also by the decreased urine output during the last few days (Figures 79 and 80) and the relative increase in water intake (Figures 81 and 82). The subjects gradually increased their capacity for work on the treadmill (see Subsection 3.4.5) and during the latter simulation days frequently performed short runs. It has been estimated that the decreased caloric intake and increased physical work during the last four days of the simulation can account for at least half of the subjects' weight loss. Increased perspiration rates probably account for the balance of the weight loss. Slight changes in muscle mass and waist circumferences together with the weight losses indicate that the subjects lost fatty tissue (Table 13).

3.4.3.2. Dry Weight Exchanges-- Tables 14 and 15 give the weights of feces produced during the simulation. The dry weight of food retained in the body (food dry weight minus feces dry weight) closely follows the dry weight of food ingested (Figures 84 and 85). The striking reduction in food intake during the last few days of the simulation is clearly illustrated in these figures.

Notable oscillations occurred in the feces weight (Figures 86 and 87). A comparison of these figures with the dry weight of the diet indicates a correlation between the period of oscillation of the diet dry weight with that of the feces weight, the period being about 5 days. This correlation is especially evident in Operator 1 (Figure 86). The amplitude of the feces wet weight oscillations and the apparent phase shifts of the total feces weight with respect to the waveform of the dry weight of the diet might be reduced by a more constant daily diet dry weight. A superposition of the dry weight of the diet waveform with that of the dry weight of the feces indicates that Operator 2's feces output took about 11 days to get aligned with the diet dry weight with respect to both phase and amplitude. Operator 1's feces dry weight output, however, had already "locked on" to the diet dry weight waveform by the time the simulation had begun and remained aligned throughout the simulation. Similar oscillations occurred in the water balance results. A longer-duration simulation using this diet could profitably have examined the effect of synchronizing of water and fecal outputs with diet water and dry weight oscillations to determine whether the amplitude of subject waste outputs increases with increasing synchronization. This subject, however, is beyond the scope of this study.

Throughout the simulation the percentage of water in the feces remained relatively constant (70 to 80 percent) for both subjects (Figures 88 and 89).

3.4.4 Urine Analyses

A limited examination of selected urine components was made. Twenty-four-hour urine samples were delivered to the Laboratory Medicine Associates of the University of Minnesota Hospital for analyses of 17-hydroxycorticosterone (cortisol) and the 17-ketosteroids approximately every third day of the simulation. Daily 24-hour urine analyses for glucose, ketones, proteins and urine pH were conducted at our own laboratories. The 17-hydroxysteroids (primarily cortisol) and 17-ketosteroids found in the urine are given in Tables 16 and 17. The average outputs of 17-ketosteroids and 17-hydroxycorticosterone are not considered abnormal. Normal urine outputs of 17-ketosteroid are about 15 mg/day (Ref. 6) with a range of about 10.5 to 21.7 mg/day (Ref. 9). Normal urine outputs of 17-hydroxysteroids range from 5 to 20 mg/day (Ref. 6). High stress levels as measured by these hormone outputs occurred on the first day of the simulation for both subjects when the excitement and activity of beginning the simulation was at its peak (Figures 90 and 91).

Operator 2's urinary output of these hormones remained relatively stable throughout the simulation, the 17-hydroxycorticosterone level dropping off to a stable value (Figure 91). Operator 1 showed elevated hormone outputs on day 10 (the ninth full day). On this day a simulated cabin pressure failure occurred. Operator 1's comment that the emergency was a "real surprise" appears to be directly reflected in his hormone output for that day. Urine analyses for these hormones was, unfortunately, not performed for the days on which the other simulated emergencies occurred. The values obtained for protein, glucose, ketones and pH were within normal limits (Tables 18 and 19).

3.4.5 Oxygen Consumption and Physical Fitness

The subjects' maximal oxygen consumption was determined prior to and immediately after the simulation.* The methods of indirect, open-calorimetry (Ref. 31) permitting the analysis of expired gasses during treadmill runs were used. The data is summarized in Table 20. The maximum oxygen consumption (measured as cubic centimeters of oxygen consumed per kilogram body weight per minute) was not significantly altered for either subject by the stay in the simulation. This fact demonstrates that the aerobic work capacity (e.g., physical fitness) of both subjects was maintained over the 18-day period through the exercise obtained from extravehicular inflated pressure suit activities without a requirement for a supplementary physical exercise regime.** Based on their maximum oxygen capacities the subjects were in good, but not excellent, physical

*Performed by Dr. Jack Alexander of the University of Minnesota Laboratory of Physiological Hygiene. The subjects performed treadmill runs at 6 mph over a three-day period with progressively increasing grades. The subjects' maximum oxygen capacity was taken as the highest rate of oxygen consumption measured with increasing treadmill grades. The results indicated that maximum oxygen capacities were reached on the first trial since the rate of oxygen consumption did not increase with increasing work loads thereafter. Oxygen consumption was measured by continuous analysis of expired gasses using a Beckman oxygen/carbon dioxide analyzer and flow meter. Heart rates were telemetered continuously during oxygen consumption determinations.

**Work done by each subject on the treadmill during the extravehicular activity was as follows:

First nine days: Two 10-minute periods at 1 mph, 4 percent grade.

Days 10 through 15: Two 10-minute treadmill profiles were run beginning at 1 mph and 4-percent grade with the speed gradually being increased to 2.6 mph where it was maintained for 3 minutes.

Days 16 through 18: In addition to the 2.6-mph profile, each subject ran for approximately one minute at speeds on the order of 5 mph.

fitness prior to the simulation (Refs. 24 and 30). (It may be reasonable to assume that the actual astronauts will be in less than optimal physical fitness after their journey to the moon in the Apollo craft, hence it is not felt that a rigorous physical fitness program prior to the LUNEX II subjects beginning the simulation would alter the validity of this study's results.)

Heart rates and oxygen consumption changes during submaximal and maximal work are shown in Figures 92 through 95 as a function of time on the treadmill. The relationships of heart rate to oxygen consumption are shown for each subject in Figures 96 and 97. The figures were obtained by fitting the data points with a straight line by the least squares method. These relationships essentially "calibrate" each subject, providing a means whereby relative oxygen consumption during various tasks performed in the simulation can be obtained directly from the heart rates measured during performance of those tasks (Ref. 24 and 25). In addition, heart and respiratory rates obtained during a variety of task performances can be treated as the ratio of the measured value, P, to the value, P_c, achieved during maximal work. This permits the comparison of each subject's physical effort as a percentage of his own steady-state maximum (Refs. 1 and 4). This treatment is utilized in subsection 3.4.7.

Selected treadmill activities performed by the subjects during the simulation are shown in Figures 98 through 102. Based on the heart rates observed during these activities and those obtained during the measurement of oxygen consumption (Figures 92 through 97), estimates were made of the oxygen consumption during inflated suit treadmill activity.* The Portable Life Support System (PLSS) currently considered allows energy expenditures of 5.04 kcal/min (1200 BTU/hr) for four hours, 6.73 kcal/min (1600 BTU/hr) for three hours and 8.40 kcal/min (2400 BTU/hr) for short periods of five to ten minutes (Ref. 21). The estimated oxygen consumption

*These estimates were made by summing the oxygen consumption per minute values corresponding to the heart rate observed each minute of the inflated suit treadmill activity.

data obtained during treadmill exercises, including walks up to 2.6 mph, showed that the rate of energy expenditure was in excess of these maximum allowable PLSS rates (Figures 98 through 102). During treadmill exercises the subjects normally walked about 0.3 mile (though occasionally 0.5-mile walks were performed) in ten minutes, usually performing two such activities during each extravehicular task. Such an effort is estimated to consume 30 (Operator 1) to 50 (Operator 2) liters of oxygen when the walking rate at times reaches 2.6 mph (see Figures 98 through 101). Thus, each operator consumed on the order of 144 to 240 kilocalories respectively in the 20-minute exercise, with rates exceeding the maximum capacity of the PLSS. These results indicate that the work done while in the inflated suit is not limited by the man's capability but by the present ability to provide the necessary oxygen through some portable system.

It is interesting to note that in suits inflated to 3.5 psi and on a four percent grade, Operator 1 changes his pace from walking to running at 4.5 to 4.8 mph; Operator 2 starts running at 5.4 mph.

Based on the known composition of protein, carbohydrate and fat in the diet and the use of standard equations for calculating metabolic rates from diets of known constituents (Ref. 9, page 197) it was calculated (for 17 full days using the actual amount consumed) that 632 liters/day of oxygen were consumed and 546 liters/day of carbon dioxide given off to give a respiratory quotient of 0.87. These calculations also showed that 368 grams/day of metabolic water was utilized. From the subjects' height, weight and age, the Basal Metabolism can be estimated (Refs. 6, 7 and 8). Operator 1 has a surface area of 1.91 square meters, and Operator 2's is 2.13 square meters as estimated from standard nomograms (Refs. 7 and 8). Knowing the surface areas, the estimated basal metabolisms are 1780 kcal/day for Operator 1 and 2000 kcal/day for Operator 2. If a total of 3000 kcal/day are utilized, then Operator 1 was working at a rate approximately 1220 kcal/day above his basal metabolism and Operator 2 at a rate 1000 kcal/day above his basal metabolism.

It is of interest to estimate the relative energy expenditure required to perform various task categories using the heart rate and oxygen consumption relationships derived for the subjects. Calculations of these relative energy expenditures in terms of the estimated oxygen consumption are presented in Tables 21 and 22. These estimates have only a relative validity, particularly the oxygen consumption estimates for tasks utilizing small muscle group activities. The estimates for tasks requiring large muscle group activity are, however, considered quite good. No correction to standard temperature and pressure conditions (STP) was made since both the oxygen consumption calibration tests and the simulator tasks occurred at comparable temperatures (~75° F) and pressures (760 mm Hg). (Converting to STP results in a reduction of oxygen values by about eight percent.)

The daily estimates calculated in this manner indicate that Operator 1 consumed on the average of 630 liters of oxygen per day whereas Operator 2 consumed 670 liters of oxygen per day. These differences are trivial when compared as oxygen consumed per kilogram of body weight. The results shown in Tables 22 and 23 indicate that the increased pressure suit activity on the treadmill during the latter half of the simulation resulted in a concomittant increased expenditure of energy. This fact is no doubt meaningful in light of the weight losses during the last three days of simulation, but it does not explain the tendency to discard food during this same time period. Trends in estimated oxygen consumption as a function of weight loss are shown in Table 23.

An independent check of the average daily oxygen consumption estimated from heart rate and body weight and surface area can be made by comparing this estimated oxygen consumption with that estimated from the metabolic equations for the processing of known food mixtures. By this latter means, it was shown that on the order of 632 liters of oxygen per day are utilized. A comparison of this figure with the 630 to 670 liters of oxygen per day estimated from heart rate and basal metabolism estimates indicates a good agreement, especially for Operator 1.

3.4.6 Heart and Respiratory Rates During the Simulation

Table 24 shows the average heart and respiratory rates for principal simulation tasks. These values are expressed as P/P_c ratios (see Subsection 3.4.5) in Table 25. It is apparent that tasks requiring large muscle group activity can be distinguished from those tasks which are basically sedentary (Figures 103 and 104). The navigation task, requiring a near standing position and limited upper torso activity was accomplished with less effort than previous simulated navigation tasks (Refs. 1 and 4). A comparison of P/P_c values shows that both subjects worked at similar levels of their maximum work capacity for any given task. No trends in heart or respiratory rates for any task was observed throughout the simulation. For this simulation, only tasks involving the active use of the pressure suit required high work outputs as measured by heart and respiratory rates (Figures 103 and 104). During outside inflated suit treadmill activity, the inlet temperature was kept at 54°F, the outlet temperature generally holding at 84° to 89°F.

3.4.7 Health and Hygiene

The subjects maintained high morale throughout the experiment. Irritability was recognized only during the latter few days of the simulation and then only when there had been an equipment failure. No inter-subject irritability was observed throughout the study. To assure subject well-being and to gain information on the effects of the confinement on the subjects while they were still exposed to a restricting environment, a complete medical examination was given each subject after they had completed 10 days in the LUNEX II. To minimize disruption of the simulation, the subjects were advised of the doctor's visit and given instructions concerning the conduct of the examination. The physical examination was performed by Dr. Milton Alter from the Department of Neurology at the University of Minnesota. The doctor entered the simulator and performed the examinations in the cabin area. During his examination of one subject, the other subject remained in the airlock -- the inner and outer airlock door being closed. The detailed examination results are given in Appendix II. Both subjects were in good physical and psychological condition. The subjects, particularly Operator 1, had mildly infected eyes. It was suggested that the infection might be related to exposure to ultraviolet light. The intensive use of microscopes and their light sources plus the driving task oscilloscope display are believed to be the cause of the eye irritation. The continued use of microscopes to perform daily tasks is also believed to be the cause of the subjects feeling deficient in depth perception upon completing the simulation study.

The subjects routinely performed hygiene tasks during the simulation. Oral hygiene was practiced after every meal using an electric toothbrush. Non-caloric chewing gum was also used at the subjects' discretion. Due to the high perspiration rates after extravehicular activities, at least one change of flight underwear and socks was required per day. (The absorbent cotton underwear quickly became soaked. Since the underwear prevented ventilating air to evaporate perspiration on the body, it is believed that body cooling due to vaporizing perspiration did not seriously effect the metabolic heat exchanges discussed in Subsection 3.4.5. Soap and water was a necessary supplement to the benzylchloride-treated cleansing swipes provided. No detrimental effect due to not shaving was noted.

3.5 SUBJECTIVE EVALUATIONS

3.5.1 Cabin Habitability

The subjects' numerical rating of the LUNEX II vehicle cabin habitability is shown in Table 26. These ratings were made mainly with the vehicle volume, sleeping accommodations, and ceiling height in mind. As such they indicate that, after two weeks, both subjects found the vehicle volume and ceiling height satisfactory. Some of the principal comments relating to cabin habitability are summarized as follows:

- The crew seats in the cockpit should be adjustable, permitting fore and aft and up and down motion and be able to be reclined 30 degrees. The seats, however, were very satisfactory for this simulation.
- A supply of hooks and nails (or their equivalent), some rope and webbing should be provided so that crewmen can place them where needed.
- Provisions should be made to allow the pressure suits to hang full length in the airlock.
- Waiting in the standing position for airlock pump-down and pump-up was very stressing (with the low ceiling height). Pressurized crewmen with backpacks should be able to sit down. Hand holds are necessary to aid in sitting down and getting up. (After installation of hand holds the subjects were able to sit down in the airlock during simulated pump-down and pump-up cycles.
- A storage shelf should be provided in the airlock for storing spacesuit helmet and gloves.
- Crew passage in the aisleway while another crew member is working in the center aisle area is awkward or impractical.
- The width of the opening to the water supply should accommodate the head of a crewman.
- The water supply should be positioned equally distant from the crew eating seats to provide both crewmen easy access. (Food preparation was a shared task; one operator rehydrated the food while the other mixed it.)
- An emergency water supply should be provided for use if the main source is interrupted.

- The swivel cockpit seats were an excellent idea. A means to lock the seats in their forward position should be provided.
- The mobile aisle seat was good; however, a slightly larger seat would be desirable. After 15 minutes sitting became uncomfortable (seat pan was approximately 29 centimeters in diameter).
- Force gradients on the hand control should be negligible. Removal of the control springs greatly reduced the irritating center null position.
- The width of the center aisle was at first thought too narrow for sleeping; however, the addition of foam rubber sleeping pads and several days' experience greatly improved sleeping.
- Head bumping on the low ceilings increased during the early part of the simulation, especially from the third day on. Installation (accomplished by the subjects) of foam rubber padding on the ceiling and around hatch-ways greatly improved the situation.
- A portable chair (camp stool variety) did not work well in the cabin. It became jammed between the front seats and was a storage problem. It was useful for checking out the pressure suits in the airlock.
- All lights should be recessed.
- Emergency operations dictate that the inner airlock hatch width be increased to accommodate pressurized spacesuits with PLSS.
- Driving hand control should 7.5 centimeters (3 inches) forward (fore) for pressurized suit operation.
- Cockpit seats were too close to the control panel for writing on the slide-out boards.
- Positive locking mechanisms are required for the airlock doors.
- Force and travel on airlock hatch wheels were good.

- The inner airlock door should definitely swing in both directions.
- After 14 days, the cabin interior volume was satisfactory, though Operator 2 (93 percent standing height) did complain of a cramped neck by the end of the day.
- The work top counter area was more than adequate.
- Reliable communications are required for all phases of this type of simulation.
- The center-aisle slide-out work board was the best area to perform sample measurement, charting and geophysical tasks.
- Storage cabinet volume was adequate. Smaller cabinet divisions would be desirable.
- The airlock volume was adequate for donning and doffing space suits, both in normal and in simultaneous two-man emergency tasks.
- The driving task was distressing to the eyes.
- Underwear and socks must be changed after each extravehicular activity.
- Interior color schemes were drab and depressing (colors were according to Apollo/LEM specs and Reference 23.)

3.5.2 Diet Evaluation

Comments on the diet were taken from the subjects' 3-, 7-, and 14-day appraisals as well as from their personal log books. Though they considered the food generally satisfactory, certain items and conditions were disliked. It was desired that specific dehydrated food items be identified on the individual package along with the quantity of hot or cold water to be added. Straws were requested for the cold drinks. Difficulty was experienced in getting cold drinks to go completely into solution upon rehydration. Coffee or a hot drink was considered to be highly desirable in the first meal of the day. Eating and drinking directly from the plastic food containers caused some irritation to the mouth due to the sharp edges on the seams of the bags. An evaluation of specific food items is presented in Table 27.

3.5.3 Simulation Evaluation

Both subjects found that it was not unduly uncomfortable to perform the assigned tasks within the confines of the LUNEX II. Prior to the simulation initiation, the subjects had serious doubts about performing tasks and living in a vehicle which did not permit them to stand up and which was apparently very restricting. Approximately four days were required to adjust to the new environment after which "there was almost a feeling of exhilaration to be able to work within such a restricted volume" (quoted from Operator 2's notes). Both men enjoyed outside activities and meal time most and found equipment failure most objectionable. Post-simulation rank ordering of the seven principle tasks showed both operators preferred the navigation and geophysical tasks the most and monitoring of the driver's off-time the least. The subjects' rank ordering of tasks (Table 28) correlated significantly at the five percent level, the Spearman Rank correlation coefficient being 0.82. Both subjects independently felt they could have continued the simulations for 21 days or longer. A summary of some of the subjects' general comments concerning the simulation follows:

- The simulator should be physically remote from the monitor stations and the associated equipment external to the simulator in order to minimize external sounds and to enhance simulation realism.
- The subjects should have more responsibility and control over simulation activities.

- The initial simulation schedule was too rigorous. An hour relaxation period during the day and cessation of task activities an hour earlier in the evening proved beneficial and was greatly appreciated.
- A tradeoff between extravehicular tasks and intravehicular scientific and routine tasks is required. Extravehicular tasks are very time consuming, resulting in serious curtailment of intravehicular task activities if more than one extravehicular activity per day is required. Detailed, time-consuming scientific tasks are not advisable.
- Equipment breakdowns or other difficulties resulting in task interruption should result in the interrupted task being deleted rather than resulting in a formidable accumulation of unfinished tasks.
- Because of the time required to prepare and ingest meals, three or even two meals a day instead of four would be desirable -- the total caloric intake being unchanged.
- Slight perturbations in a functional task time line can disturb the schedule by several hours. Extensive crew training with operational state-of-the-art equipment would be required to refine and make operational a real-mission time line.
- Individual donning of a PLSS by an operator in the inflated suit will require further study.
- Sitting became uncomfortable after about seven days.
- The simulation was unrealistic due to lack of system and equipment sophistication. The proximity to the monitors and interaction with the test conductors further reduced the simulation realism.

Both subjects felt that further study is needed in the areas of emergencies and meal consumption (i.e., the number of meals per day and the caloric content of each meal). One of the subjects stated that their morale was very high the first week, then fell off to a plateau which was maintained throughout the remainder of the simulation.

3.6 CABIN PARAMETERS

Throughout the simulation, the subjects made adjustments and additions to the cabin interior. Hooks were installed to support food sacks, thus conserving work-top space and preventing rapid heat transfer between hot and cold items which occurs when the items come in contact after mixing (Figure 9). Handholds were installed in the airlock and main cabin area to facilitate mobility in inflated pressure suits. The ceiling of the cabin and airlock was covered with a half-inch layer of plastic foam padding on day 10 of the simulation. This padding greatly alleviated the discomfort of the low ceiling.

The cabin ventilation flow rate could be controlled by opening or closing ventilation louvers in the cabin. Normally the cabin ventilation was kept near maximum during the day and decreased by about 50 percent at night. This variation was maintained at the subjects' request in order to prevent the subject from becoming cold during sleeping hours. Figure 105 shows representative temperature fluctuations of the simulator cabin. As can be seen on this figure, the temperature of the vacated cabin with maximum ventilation rates was about 20° C (68° F). The cabin temperature is elevated about 2 to 4.4° C (4 to 8° F) by heat given off by the subjects. A consistent rise in cabin temperature occurred each morning when subject activity commenced. Cabin temperature was generally about 23° C (75° F) with fluctuations of ±1.4° C (±2.5° F) occurring due to varying subject activities.

3.7 TIME LINE EVALUATION

Task activities initially followed the sequence shown in Figure 40. Though the experimenters knew from previous studies (Ref. 1) approximately the times required to perform the tasks, these times were not given to the subjects. The object was to empirically derive new task times for these subjects and tasks. By day 4 of the simulation, the subjects (and the experimenters) were able to successfully complete the sequence of activities, with times assigned for each task (see Figure 106). The times to complete grouped tasks are shown in Table 29. Completing tasks within these time constraints was found to cause excessive fatigue and stress in the subjects. More personal time was then allotted to the subjects.

Suit donning and doffing time was reduced by performing a "crew exchange" for extravehicular tasks. The crew exchange required each subject's extravehicular activity to take place at a single location on the simulated traverse, one subject egressing from the vehicle immediately after the first subject had ingressed from his outside activity. This procedure required each subject to don and doff his suit only once a day instead of twice a day, with a total time saving of about 2 hours.

After several days of trial and error, a functional time line was developed, the final version being a direct result of the subjects' efforts to include all tasks in a manner most satisfactory to them (the detailed task sequences performed on each day are shown in Figure I-17 of Appendix I). The final LUNEX II time line is shown in Figure 107 (block diagram of this time line is shown in Figure I-18 of Appendix I.) The times to complete grouped tasks are shown in Table 30. This time line went into effect on the 12th day of the simulation and continued successfully thereafter.

Though it was not possible in this simulation to spend extended time periods performing outside tasks, it became obvious that if more time is to be spent outside the vehicle this could be accomplished by devoting whole days to extravehicular tasks (assuming the pressure suits and support systems are adequate). On these days little or no vehicle driving would occur nor would any inside scientific tasks be performed. Likewise, to accomplish inside tasks, full days with no extravehicular activities may be required. This suggests that, by alternating inside and outside tasks by days, a realistic time line could be generated. It should be noted that housekeeping and hygiene require a considerable time allotment if undue stress on the crew is to be prevented.

SECTION 4
DISCUSSION

The outstanding result of this simulation was that two qualified subjects could maintain daily performance levels and physical condition for an 18-day simulation with no observable adverse effects or trends that could be attributed to either the minimal interior free volume of the simulator or to the duration of time spent in the simulator.

For the task conditions and performance measures of this simulation a workspace/living area having a 166-centimeter (65.4-inch) ceiling height and a volume of 3.26 cubic meters (115.3 cubic feet) was found to be adequate for a full-term lunar surface mission simulation plus a 4-day contingency. Both the workspace/living area volume and the airlock volume [1.36 cubic meters (48 cubic feet) normal, 1.86 cubic meters (65.9 cubic feet) emergency] were found satisfactory for two men to simultaneously don and pressurize state-of-the-art pressure suits.

The general finding that vehicle interior volumes, workspace layouts and sleeping and comestible provisions were adequate for an 18-day simulation wherein crew performance was evaluated by physiological and performance parameters under different pressure suit conditions provides a successful validation of previous short-term studies performed by Honeywell (Refs. 1, 2, 3, and 4). The one other minimum crew space habitability study for a lunar mission known to us (Ref. 19) evaluated a volume of 61.5 cubic feet per man. The Apollo-capsule-shaped vehicle used in this other study did not provide an airlock for egress to the lunar surface, nor was the vehicle shape intended to be particularly suited for lunar surface exploration.

In the present study, the normal vehicle interior free volume of 4.62 cubic meters (163.3 cubic feet) or 2.31 cubic meters (81.7 cubic feet) per man included the airlock, which, though used for hygiene purposes, was generally not occupied by the subjects during routine inside tasks. The workspace/ living area of 3. 26 cubic meters (115. 3 cubic feet) provided 1. 63 cubic meters (57. 7 cubic feet) per man. This small functional volume was possible principally by the lowered ceiling height and by the careful shaping of workspace and living area geometries. The basic cylindrical shape of the LUNEX II corresponds to the accepted shape for a lunar surface roving vehicle. Other studies have examined as many as 1200 vehicle design combinations resulting in the choice of a basically cylindrical shape (Ref. 11).

The minimum cabin volume for a lunar surface vehicle appears to be set by emergency conditions which require the use of pressurized suits. The emergency study results indicated that the cabin aisle width and the inner airlock door need widening to accommodate a crewman in the inflated suit wearing a backpack. It was clear that a larger inner hatch is required to permit easy access by subjects wearing inflated suits with the backpack on. More efficient utilization of the hatch space could be achieved if a sliding instead of a swinging hatch door were used. Repetitive trials and procedure refinement may result in an acceptable means of operating in a minimum-volume vehicle during emergency conditions. The negotiating of hatches and aisles is, however, a persistent problem in the inflated suit condition and has been so recognized in other studies (e. g., Ref. 20, p. 69).

No remarkable physiological effects were observed during the study with the exception of the weight loss during the last few days of the simulation. Several explanations may be given for the weight loss phenomena. A most likely explanation can be derived by piecing together diverse occurrences which, in combination, may have resulted in the loss of weight. At about day 12 of the simulation, the subjects were following a time line largely of their own design and were highly motivated to complete all tasks within its constraints. The time required to eat four meals a day was considered excessive and, with the relatively light physical workouts during the early phase of the simulation, they could quite easily discard certain food items without feeling hunger. Their gradual adaptation to work on the treadmill in the inflated suit condition, however, led to increased workload during outside activities since it was the experimenter's intent to increase the physical effort of the treadmill activity to exceed if possible the known capacity of the PLSS and thus assure appropriate physiological stress during outside task periods considerably shorter than the 4-hour maximum period (Ref. 21) allotted for an actual mission. During the last few days of the simulation the subjects were willing to accept high levels of work during extra-vehicular activities. This high workload level coincided with their determination to make the time line work, resulting in food being discarded just when its caloric content was most needed, with the result that the subjects began taking in less food while expending more energy per day.

Dehydration did not appear to occur since water excreted in the urine and feces declined during the latter simulation days while water intake was maintained, permitting more water to be lost as perspiration (see Figures 81 and 82) with total water balance being maintained. The weight loss is not believed due to the stay in the simulator. It is believed that performance as well as physiological disturbances resulted more from anxiety-producing stimuli such as emergencies, equipment breakdown, and the accumulation of uncompleted tasks than from the simulator confinement per se. This observation is in agreement with the findings of Hanna in an 8-day simulated space vehicle confinement study wherein selected physiological parameters were monitored (Ref. 22). Speckman and co-workers found no physiological changes from pre-test control values during confinement studies 28 days long (Ref. 26).

It should be noted that the LUNEX II simulation was neither an isolation nor a confinement study in the strict sense of these terms. The subjects were confined to a schedule as much as to a vehicle since outside activities (within the confines of a pressurized space suit) were performed with occasional visual and verbal interaction with the experimenters -- notably during emergency rescue tasks. Ninety-six percent of the subjects' time, however, was spent within the confines of the LUNEX II.

The technique of calibrating each subject's heart rate with his maximum oxygen capacity (Refs. 24 and 25) provided a relatively simple means whereby relative task workloads can be assigned (when the task requires the use of large muscle groups). This approach appears desirable for simulation studies where the number of subjects is usually small and heart rates may be monitored. The consideration of heart rate and respiratory rates as a percentage of maximum steady-state values eliminates dependence on large numbers of subjects to allow for inter-subject variations (Ref. 1). The P/P_c values obtained for the two subjects during this simulation were found to be comparable to those values for other subjects performing the same or similar tasks in a previous Honeywell study (Refs. 1 and 4).

Further studies in the areas of emergencies and optimizing food consumption times are recommended. In addition, it would be highly desirable to adapt the low cabin interior volumes and their workspace layouts to actual system hardware as these hardware systems become defined for lunar surface vehicles.

This study has demonstrated that careful workspace layouts can make a small vehicle volume habitable and functional using the tasks simulated. The results obtained can be used in the definition of operational workspace and stowage areas for the use and stowage of actual mission hardware.

SECTION 5
CONCLUSIONS

Each of the task result sections present specific conclusions which will not be listed here. Instead a summary of the major general results are presented.

1. A lunar surfaee vehicle with a cabin free volume of 3.26 cubic meters (115.3 cubic feet), a nominal airlock volume of 1.36 cubic meters (48 cubic feet), and a ceiling height of 166 centimeters (65.4 inches) is adequate to house two men (47 to 93 percentile with respect to height) performing simulated lunar surface mission tasks for 18 days.

2. Simulated driving, monitoring, navigating, sample measurement and audio balancing tasks could be performed throughout the simulation with satisfactory accuracy and no adverse trends. No unusual differences between the two subjects' performance levels were observed.

3. Realistic geophysical tasks could be successfully performed in the simulator by subjects relatively untrained in geology.

4. Performance during emergencies indicated that:

   - Power assistance is required for the rescue of a simulated totally disabled crew member.
   - Emergency procedures are critical to mission success. Further study of the emergency procedures and techniques is recommended.
   - An airlock having a volume of 1.86 cubic meters (65.9 cubic feet) and a ceiling height of 166 centimeters (65.4 inches) will adequately

contain two operators in inflated pressure suits, one operator being totally immobilized. Furthermore, an airlock of these dimensions permits two crew members to simultaneously don pressure suits and backpacks and inflate their Apollo state-of-the-art pressure suits.

- The cabin volume, driving station volumes, and chair locations were adequate for operating in the inflated pressure suit condition using the cabin air supply system. Performance of the driving and monitoring tasks while wearing suits deteriorated.
- A 55.8-by 127-centimeter (22 x 50-inch) inner hatch space could not accommodate subjects wearing pressurized suits and backpacks.
- A single crew member could successfully perform simulated tasks within the minimum cabin volume for at least 7 hours even if one crew member was temporarily disabled.

5. A diet yielding the caloric equivalent of approximately 3000 calories per day provided sufficient nutrient for the performance of the simulation tasks.

6. The urine analyses showed no abnormal deviations with respect to pH, glucose, ketones, proteins, 17-hydroxy corticosterone and the 17-ketosteroids during the 18 day simulation.

7. The physical fitness of the subjects was unchanged by the simulation as determined by pre- and post-simulation maximal oxygen consumption measurements taken during treadmill runs. This result indicated that the daily exercise during extravehicular treadmill walks maintained fitness over an 18-day period without a scheduled in-cabin exercise program. Extravehicular exercise consisted of one-third to one-half-mile walks at speeds from 1 to 2.6 miles per hour while wearing pressure suits inflated to 3.5 pounds per square inch above atmospheric.

8. Oxygen consumption estimated during treadmill walks on 4 percent grades up to 2.6 miles per hour while wearing inflated pressure suits exceeds the rated capacity of the PLSS, indicating that extravehicular activity is limited by system constraints rather than operator capabilities.

9. Heart and respiratory rates, treated as a percent of steady-state maximums attained during fatiguing work, clearly distinguish between tasks requiring large or small muscle group activities.

10. Task time-line analyses suggest that, in order to increase the time available for inside scientific tasks, no more than three meals a day should be required. Time is also saved if subjects simultaneously don and doff pressure suits and exchange inside-and -outside vehicle tasks.

11. It is recommended that extravehicular tasks be alternated by day with inside tasks to permit maximum task performance efficiency.

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TABLES

Table 1. LUNEX II Volumes

Duty Station	Free Volume *		Storage/Equipment Space**		Totals
		Subtotal		Subtotal	
Driving Area	1.70m^3 (60.2 $ft.^3$)	3.26m^3 (115.3 $ft.^3$)	0.72m^3 (25.4 $ft.^3$)	2.79m^3 (98.5 $ft.^3$)	6.05m^3 (213.8 $ft.^3$)
Work Space/Living Area	1.56m^3 (55.1 $ft.^3$)		2.07m^3 (73.1 $ft.^3$)		
Airlock ***		1.36m^3 (48.0 $ft.^3$)		1.18m^3 41.9 $ft.^3$	2.54m^3 (89.9 $ft.^3$)
Totals		4.62m^3 (163.3 $ft.^3$)		3.97m^3 (140.4 $ft.^3$)	8.59m^3 (303.7 $ft.^3$)

* These volumes represent the actual Lunex II free volume--excluding all irregular projections and including all space accessible to the crew with the exception of storage space.

** These volumes represent space occupied by the equipment inside the Lunex II (such as the chairs) and all interior space usable for equipment storage.

*** Under emergency conditions the airlock volume could be increased to 1.86 cubic meters (65.9 $ft.^3$) with the airlock storage space being reduced accordingly to 0.68 cubic meters (24.0 $ft.^3$).

Table 2. Cabin Illumination

Area	Foot Candles
1. Work station behind driver	30
2. Center pullout work station	16
3. Audio balance work station	28
4. Work station behind monitor	28
5. Water closet	1
6. Flow meter light in airlock	4
7. Seat in airlock	<1
8. Driver's station workboard	23
9. Driver's station panel	15
10. Driver's station display scope area	3
11. Monitor's station workboard	14
12. Monitor's station panel	10
13. Monitor's station window area	4
14. Intensity desired for driving	1

Table 3. Cabin Electrical Controls and Indicators

Work Area	Item	Function
Driving	Push to talk toggle switch	Enables subjects to communicate with test conductors.
	Control stick	Used right and left motions of the stick to track the driving task display.
	Dual-beam scope display	Visible only during driving task to display parallel line "road" and tracking dot.
Center Cockpit Panel	Driver's back and side light controls	To adjust intensity of back and side cockpit lights.
	Communications microphone-speaker	Audio contact with experimenters.
	Hatchlights	Indicate that inner or outer hatch is open.
	Monitor's back and side light controls	To adjust intensity of back and side cockpit lights.
	Cockpit time switch	To turn cockpit clock timer on or off.
	Cockpit timer light	To indicate timer power is on.
Monitoring	Cockpit lights power switch	To turn cockpit lights power transformer on or off.
	Push to talk toggle switch	Enables subjects to communicate with test conductors.
	Off course monitor light	Indicates that driver is off course.
	Monitor button switch	Operates "Monitor" clock timer in external equipment rack.
	Helmet communications jack	Provides communications to operator wearing helmet inside main cabin area.
	3 x 3 light matrix	Dual-purpose display for "change-no change" monitoring task and skill retention task.

Table 3. Cabin Electrical Controls and Indicators (Continued)

Work Area	Item	Function
Monitor (cont.)	"Yes" Button switch (switch no. 1)	To be operated when surveilance task light pattern changes from previous pattern.
	"No" Button switch (switch no. 2)	To be operated when surveilance task light pattern remains identical to previous pattern.
	3rd Button switch (switch no. 3)	To be operated along with the "yes"-"no" button switches as required by the skill retention task.
Port Work Station	Airlôck pump cycle toggle switch	Up position initiates 5 minute "pump up" timer. Down position initiates 5 minute "pump down" timer. Center position is off.
	Pump cycle "on" light	Indicates that either "pump up" or "pump down" cycle is on.
	Switch on light fixture	Operates port duty station light.
	Power outlet on light	110V power for portable lights, tools, etc.
Starboard Work Station	Timer switch	To turn work station clock timer on or off.
	Timer Light	Indicates timer power is on.
	"Power on" switch	Power switch for audio balancing generator.
	Red light	Indicates generator power is on.
	"Headphones on" switch	Initiates audio balancing task and task clock timer.
	"Headphones" jack	Headphone connection for audio balancing task.
	Toggle switch on communications box	Push to talk switch for use in center cabin work area.
	Switch on light fixture (2)	Operate starboard duty station lights.

Table 3. Cabin Electrical Controls and Indicators (Concluded)

Work Area	Item	Function
Starboard Work Station (cont.)	Pitch axis meter	Pitch axis gimbal position indicator.
	Pitch axis thumb wheel	Pitch axis gimbal position adjustment.
	Yaw axis meter	Yaw axis gimbal position indicator
	Yaw axis thumb wheel	Yaw axis gimbal position adjustment.
Airlock	Airlock pump cycle switch	Up position initiates 5 minute "pump up" timer. Center position is off.
	Pump cycle "on" light	Indicates that either "pump up" or "pump down" cycle is on.
	Airlock light on switch	Main airlock light power switch.
	Airflow indicator light on switch	Airflow indicator light power switch.

Table 4. Physical Dimensions of LUNEX II Subjects (Pre-Simulation)

Parameter	Operator 1 Age: 38			Operator 2 Age: 34		
	Metric	British	Per-centile	Metric	British	Per-centile
Height	175 cm	69.0 in.	47	185 cm	72.9 in.	93
Weight	75.8 kg	167.0 lb	60	88.8 kg	195.8 lb	92
Sitting Height	89.4 cm	35.2 in.	28	95.7 cm	37.6 in.	91
Waist Circumference	80.7 cm	31.8 in.	51	90.2 cm	35.5 in.	86
Chest Circumference	96.5 cm	38.0 in.	39	109 cm	43.0 in.	94
Biceps Circumference	34.3 cm	13.5 in.	75	35.9 cm	14.1 in.	90
Forearm Circumference	30.5 cm	12.0 in.	75	30.8 cm	12.1 in.	80
Calf Circumference	38.1 cm	15.0 in.	73	40.6 cm	16.0 in.	95
Thigh Circumference	57.3 cm	22.6 in.	54	61.3 cm	24.1 in.	83
Arm Length	88.0 cm	34.6 in.	51	89.5 cm	35.3 in.	65
Functional Arm Length	80.6 cm	31.8 in.	36	85.1 cm	33.5 in.	77

(The measurements and percentile ratings were taken in accordance with Reference 5)

Table 5. Relationship of Driving Task Error to Navigation Task Map Location

Driving Task Integrated Error (e) (In mm displacement of recorder traces)	Location on Navigation Map
$0 < e \leq 12$	No error, placed directly on traverse
$12 < e \leq 20$	Medium error, placed intermediate distance off traverse
$20 < e \leq 45$	Maximum error, placed maximum distance off traverse

Table 6. Monitoring Error (expressed as the difference between the time the monitors switch was depressed and the driving off-course time averaged per 5 minute driving period; all times are in seconds)

Day	Operator 1				Operator 2				Both Operators			
	Speed 1		Speed 2		Speed 1		Speed 2		Speed 1		Speed 2	
	Δ Time	± S.D.	Δ Time	±S.D.	Δ Time	± S.D.	Δ Time	± S.D.	Δ Time	± S.D.	Δ Time	± S.D.
1	---	---	---	---	28.8	6.0	21.7	8.6	---	---	---	---
2	27.5	8.5	30.5	14.5	34.2	4.8	41.1	6.2	29.7	8.0	34.0	13.1
3	---	---	---	---	47.7	3.9	58.2	12.4	---	---	---	---
4	10.1	3.4	15.0	7.7	25.8	8.3	32.5	13.1	18.0	10.1	23.7	13.8
5	5.3	3.2	16.3	10.4	33.1	8.2	28.2	10.3	19.2	15.9	22.2	11.5
6	7.9	7.4	7.0	5.6	23.2	6.7	20.3	4.5	15.6	10.5	13.2	8.5
7	---	---	---	---	---	---	---	---	---	---	---	---
8	---	---	---	---	---	---	---	---	---	---	---	---
9	---	---	---	---	12.5	4.6	14.0	1.5	---	---	---	---
10	---	---	---	---	12.5	7.0	4.3	4.2	---	---	---	---
11	1.4	1.3	3.0	2.0	20.6	10.8	13.0	33.6	11.0	12.5	8.0	6.0
12	3.0	2.7	2.3	1.7	11.8	3.5	17.3	13.6	7.4	5.5	9.8	12.0
13	5.4	6.4	6.7	6.4	5.7	2.1	20.2	21.5	5.5	4.4	13.4	16.4
14	8.5	5.9	11.4	9.6	77.4	9.9	81.8	12.8	42.9	37.6	46.6	39.1
15	1.7	2.2	2.6	1.6	20.4	12.4	20.8	10.8	11.1	12.9	11.7	12.1
16	2.7	2.9	4.0	2.8	---	---	---	---	---	---	---	---
17	0.3	0.1	0.5	0.4	57.5	10.4	54.7	9.2	28.9	31.3	27.6	29.6
18	1.6	1.3	1.4	1.1	23.9	19.6	13.4	7.5	12.7	17.6	7.4	8.1
19	---	---	---	---	11.8	4.2	12.9	3.5	---	---	---	---
Averages	7.7	8.7	10.0	9.8	27.8	18.5	28.6	18.5	18.8	10.8	20.7	12.0

Table 7. Data Summary Sheet -- Change/No-Change Monitoring Task

Operator 1

Trial Number	Correct Responses	Incorrect Responses	No. of Presentations	% Right*	% Wrong*
1	365	23	417	87	5.5
3	397	43	459	86	9.4
5	423	29	455	93	6.4
7	348	26	391	89	6.7
10	430	31	472	91	6.6
12	451	32	488	92	6.6
14	428	26	460	93	5.7
16	352	23	399	87	5.7
18	473	28	519	91	5.4
20	490	21	519	93	4.1
23	522	38	569	92	6.7
25	422	27	458	92	5.6
27	444	22	469	95	4.7
29	412	9	424	98	2.0

Operator 2

Trial Number	Correct Responses	Incorrect Responses	No. of Presentations	% Right*	% Wrong*
2	400	44	468	86	9.4
4	430	18	466	92	3.9
6	437	10	466	94	2.1
8	502	17	545	92	3.1
9	451	11	481	94	2.3
11	481	27	535	90	5.1
13	416	12	456	91	2.3
15	467	33	535	87	6.2
17	494	14	524	94	2.7
19	435	15	467	93	3.2
21	513	14	555	93	2.5
22	529	25	566	94	4.4
24	412	36	452	91	8.0
26	483	11	504	96	2.2
28	509	4	448	114	0.9
30	451	13	470	96	2.9

*The percent right is independent of the percent wrong since, during each 1.5-second presentation of a 40-minute trial, the subjects could make no response, one response either correct or incorrect, or several responses correct or incorrect.

Table 8. Individual Operator Performance (Averaged per Trial over the 18 days)

Task	Speed	Operator 1		Operator 2	
		Track Off-Time (sec)	Error (mm)	Track Off-Time (sec)	Error (mm)
Driving	1	39.4 ± 16.5	20.6 ± 7.5	18.4 ± 14.1	12.1 ± 3.6
	2	40.3 ± 21.1	22.1 ± 9.0	23.7 ± 15.4	14.2 ± 5.4
Monitoring of drivers off-course time		Error (% of Off-Time)		Error (% of Off-Time)	
	1	41.8 ± 8.7		70.5 ± 18.5	
	2	42.3 ± 9.8		71.0 ± 18.5	
Navigation	*	Time (sec)		Time (sec)	
		367.4		405.6	
		Chart Error (miles)		Chart Error (miles)	
		0.55		0.54	
Audio Balance		Time (sec)		Time (sec)	
		13.50 ± 8.08		14.44 ± 4.05	
		Error (cycles)		Error (cycles)	
		15 ± 9		9 ± 10	
Sample Measurement		Time (sec)		Time (sec)	
		200.5		171.9	
		Error (0.001 in.)		Error (0.001 in.)	
		0.81 ± 0.47		0.44 ± 0.31	

*Navigation task charting time was a shared task, the subjects alternating in installing the periscope and performing sightings.

Table 9. Rock Sample Evaluation

Rock Category	Grade
1	Four right, one wrong - belonged in category 2 (close)
2	Three right, two wrong - one belonged in category 8, one belonged in category 5
3	All correct
4	Eleven right, one wrong - was identical to rock already placed in category 5
5	All correct
6	All correct
7	Near miss (no rocks of this category were included)
8	All correct

Summary:

Only one bad error - in category 2.

Two moderate errors of placing the same rock (a vesicular basalt in categories 2 and 4 as well as in the proper category 5.)

Evaluation:

Very good to excellent.

Table 10. Results of Mineral Points Count Derived from the Subjects' Data

Percentage of Mineral in Each Size Range by Number				
Mineral	Mesh Size			
	A (large)	B (medium)	C (small)	Totals
Quartz	2	5	64	71
Pyrite	3	5	6	14
Pyroxine	2	5	8	15
Totals	7	15	78	100

Actual Percentages Predetermined by Weight				
Mineral	Mesh Size			
	A (large)	B(medium)	C (small)	Totals
Quartz	5	10	30	45
Pyrite	20	10	5	35
Pyroxine	5	10	5	20
Totals	30	30	40	100%

Evaluation: Good

Table 11. Water Balances (averaged over 17 simulation days - ml/man/day)

Subject	Intake				Output				
	Food Rehydration	Extra Fluid Intake	Metabolic* Water	Total	Urine	Feces	Sweat**	Insensible**	Total**
Operator 1	2155	362	368	2885	1329	112	-	-	-
Operator 2	2155	202	368	2725	902	93	-	-	-
Averaged over subjects	2155	282	368	2805	1116	103	-	-	-

*Calculated from the known quantities of protein, carbohydrate and fat in the simulation diet according to Reference 9, p. 197.

**Water available for sweat, insensible perspiration and respiratory loss is the difference between the total water intake and that put out in the urine and feces. These values are 1444 ml for Operator 1 and 1730 ml for Operator 2 on a daily basis.

Table 12. Weight Changes During Presimulation and Simulation Period

Study Phase	Date	Simulation Day	Weights			
			Operator 1		Operator 2	
			Metric (kg)	British (lbs)	Metric (kg)	British (lbs)
Pre-Simulation	2/15	-	76.6	169.0	89.7	198.0
	2/16	-	77.0	170.0	90.3	199.0
	2/17	-	76.4	168.5	89.3	197.0
(Day Simulation Starts)	2/20	1	75.6	167.0	88.6	195.8
Simulation	2/28	8	77.0	170.0	89.0	196.2
	3/6	14	78.0	172.0	88.8	196.0
Post-Simulation	3/10	18	75.0	165.3	86.2	190.0

Table 13. Physical Dimensions of LUNEX II Subjects
(Pre-vs Post-Simulation)

Parameter	Operator 1				Operator 2			
	Before		After		Before		After	
	Metric	British	Metric	British	Metric	British	Metric	British
Weight	75.8 kg	167 lb	75.0 kg	165.25 lb	88.8 kg	195.75 lb	86.1 kg	190.0 lb
Waist Circumference	80.7 cm	31.8 in	79.4 cm	31.3 in	90.2 cm	35.5 in	86.4 cm	34.0 in
Chest Circumference	96.5 cm	38.0 in	96.5 cm	38.0 in	109 cm	43.0 in	106 cm	41.8 in
Biceps Circumference	34.3 cm	13.5 in	35.6 cm	14.0 in	35.9 cm	14.1 in	36.8 cm	14.5 in
Forearm Circumference	30.5 cm	12.0 in	31.1 cm	12.3 in	30.8 cm	12.1 in	31.8 cm	12.5 in
Calf Circumference	38.1 cm	15.0 in	36.8 cm	14.5 in	40.6 cm	16.0 in	38.7 cm	15.3 in
Thigh Circumference	57.3 cm	22.6 in	57.2 cm	22.5 in	61.3 cm	24.1 in	59.7 cm	23.5 in

Table 14. Feces Weights - Operator 1

Total Stool (18 Days)	2584.5 gm
Wet Matter	2001.2 gm
Dry Matter	583.3 gm
Average Daily Stool	107.6 gm
Average Daily Wet Matter	83.4 gm
Average Daily Dry Matter	24.3 gm
Average % Wet Matter	77.4%
Totals Omitting First and Last 1/2 Days (17 Days)	
Total Stool	2446.3 gm
Wet Matter	1898.1 gm
Dry Matter	548.2 gm
Average Daily Stool	143.9 gm
Average Daily Wet Matter	111.7 gm
Average Daily Dry Matter	32.3 gm
Average % Wet Matter	77.5%

Table 15. Feces Weights - Operator 2

Total Stool (18 Days)	2222.4 gm
Wet Matter (total)	1696.8 gm
Dry Matter (total)	525.6 gm
Average Daily Stool	101.0 gm
Average Daily Wet Matter	77.1 gm
Average Daily Dry Matter	23.9 gm
Average % Wet Matter	76.3%
Totals Omitting First and Last 1/2 Days (17 Days)	
Total Stool	2055.1 gm
Wet Matter	1575.5 gm
Dry Matter	479.6 gm
Average Daily Stool	120.9 gm
Average Daily Wet Matter	92.7 gm
Average Daily Dry Matter	28.2 gm
Average % Wet Matter	76.6%

Table 16. Urine Analysis of 17-Keto and Hydroxy Steroids - Operator 1

Full Simulation Day	Urine Vol	17-Keto	17-OH Cort
0	654 ml/12 hr.	9.3 mg/12 hr. 18.6 mg/24 hr.*	7.6 mg/12 hr. 15.2 mg/24 hr.*
3	2178 ml/24 hr.	14.4 mg/24 hr.	10.1 mg/24 hr.
6	1080 ml/24 hr.	11.9 mg/24 hr.	9.9 mg/24 hr.
10	1778 ml/24 hr.	16.5 mg/24 hr.	15.5 mg/24 hr.
13	1631 ml/24 hr.	12.8 mg/24 hr.	Lab accident
15	2474 ml/24 hr.	10.5 mg/24 hr.	18.2 mg/24 hr.
17	960 ml/24 hr.	13.3 mg/24 hr.	12.1 mg/24 hr.
	Average	14.0 mg/24 hr.	13.5 mg/24 hr.
	Average excluding first day	13.2 mg/24 hr.	13.2 mg/24 hr.

*Extrapolated to 24 hours

Table 17. Urine Analysis of 17-Keto and Hydroxy Steroids - Operator 2

Full Simulation Day	Urine Vol	17-Keto	17-OH Cort
0	743 ml/12 hr.	16.7 mg/12 hr. 33.4 mg/24 hr.*	9.8 mg/12 hr. 19.6 mg/24 hr.*
3	842 ml/24 hr.	20.4 mg/24 hr.	14.2 mg/24 hr.
6	877 ml/24 hr.	16.6 mg/24 hr.	12.6 mg/24 hr.
10	987 ml/24 hr.	17.9 mg/24 hr.	9.5 mg/24 hr.
13	1036 ml/24 hr.	18.3 mg/24 hr.	Lab accident
15	932 ml/24 hr.	17.4 mg/24 hr.	9.7 mg/24 hr.
17	808 ml/24 hr.	19.1 mg/24 hr.	9.7 mg/24 hr.
Average		20.4 mg/24 hr.	12.6 mg/24 hr.
Average Excluding 1st day		18.3 mg/24 hr.	11.1 mg/24 hr.

* Extrapolated to 24 hours.

Table 18. Urinalysis - Operator 1

Simulation Day	Protein	Glucose	p^H	Ketones	Comment
0	-	-	6.0	-	
1	-	-	6.0	-	
2	-	-	6.0	-	
3	-	-	6.5	-	
4	Trace	-	7.0	-	
5	-	-	6.5	-	
6	-	-	6.0	-	
7	Trace	-	6.5	-	
8	-	-	6.0	-	Much mucus
9	-	-	7.0	-	
10	Trace	-	6.5	-	
11	Trace	-	6.0	-	
12	-	-	6.5	-	
13	Trace	-	7.0	-	
14	-	-	6.0	-	
15	-	-	6.5	-	
16	Trace	-	6.0	-	Much amorphous material; Ca-Ox crystals
17	Trace	-	6.0	-	Much amorphous material; Ca-Ox crystals

Table 19. Urinalysis - Operator 2

Simulation Day	Protein	Glucose	p^H	Ketones	Comment
0	-	-	5.0	-	
1	-	-	6.0	-	
2	Trace	-	6.5	-	
3	-	-	6.0	-	
4	Trace	-	5.0	-	
5	Trace	-	6.0	-	
6	Trace	-	6.0	-	
7	Trace	-	6.0	-	Sedimentation
8	Trace	-	6.0	-	Much amorphous material
9	Trace	-	6.0	-	Much mucus
10	-	-	6.0	-	
11	Trace	-	6.0	-	
12	Trace	-	6.0	-	
13	-	-	6.0	-	
14	-	-	6.0	-	
15	Trace	-	6.0	-	
16	Trace	-	6.0	-	Much amorphous material; many Ca-Ox crystals
17	Trace	-	6.0	-	Much amorphous material; many Ca-Ox crystals

Table 20. Work Capacity Determinations Before and After the LUNEX II Simulation

Subject	Submaximal Work*				Maximal Work**			
	Pulse Rate		0_2 Consumption (cc/kg/min)		Pulse Rate		0_2 Consumption (cc/kg/min)	
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
Operator 1	135	138	26.6	26.6	175	---	36.8	36.2
Operator 2	143	163*	26.0	30.6*	183	181	37.2	37.1

* Submaximal Work -- 10 minute walk, 10% grade, (3 mph) 4.8 kmph

** Maximal Work -- 2:45 minute run, 6% grade, (6 mph) 9.6 kmph

T_1 : pre-simulation

T_2 : post simulation

* Operator 2 performed a 15 minute walk

Table 21. Estimated Average Daily Oxygen Consumption

Task (i)	Task Minutes Performed per Day (X)	Average Heart Rate (beats/minute)		Estimated Oxygen Consumption			
				liters/minute (Y)		liters/day	
		Operator 1	Operator 2	Operator 1	Operator 2	Operator 1	Operator 2
1) Sleeping	480	54	61	0.26[a]	0.29[a]	125	139
2) Resting; writing	120	~72	~74	0.3[b]	0.3[b]	36	36
3) Audio balancing, Driving, eating Monitoring, Sample measurement, hygiene, Navigation and Geophysical Tasks	750 (all low work load tasks)	70 to 80	75 to 85	0.5[c] (0.3 to 0.4[d])	0.5[c] (0.9 to 1.1[d])	375 (263)	375 (750)
4) Suit Donning and Doffing	60	100 to 110	110 to 115	1.0 to 1.25[d] ~1.1	1.68 to 1.74[d] ~1.7	66	102
5) Pressurized Treadmill Activity:							
1 mph	20 min first 9 days	112	125	1.3[d]	2.1[d]	26	42
2.6 mph profile	20 min last 9 days	148	155	2.2[d]	2.8[d]	44	56
Run	2 min (last 3 days)	170	184	2.7[d]	3.5[d]	49	63

Calculated over-all daily average -

Operator 1: 630 liters oxygen/day
Operator 2: 670 liters oxygen/day

a) Based on Basal Metabolic Rate calculated from surface areas and body weight.
b) Estimated from standard sources (References 8, 9 and 24).
c) Obtained from Figures 80 and 82 and actual oxygen consumption recording traces from the standing subjects.
d) Obtained from Figures 84 and 85.

Table 22. Oxygen Consumption Calculations

Estimated daily oxygen consumption was calculated according to the following equation:

$$\sum X_i Y_i = \text{oxygen consumed per day}$$

where

X_i = minutes task is performed per day
Y_i = liters of oxygen consumed per minute for
i = 1, 2, ... 5; i being the number of grouped task activities per day.

Operator 1

$$(480)(0.26) + 120(0.3) + 750(0.5) + 60(1.1) + \left\{\begin{array}{l} 20(1.3) \\ 20(2.2) \\ 20(2.2) + 2(2.7) \end{array}\right\}$$

$$= 125 + 36 + 375 + 66 + \left\{\begin{array}{l} 26 \\ 44 \\ 49.4 \end{array}\right\} = \left\{\begin{array}{l} 622 \text{ liters/day : 1st 9 days} \\ 640 \text{ liters/day : 10th through 15th day} \\ 645 \text{ liters/day : 15th through 18th day} \end{array}\right\}$$

Totals: 9(622) + 6(640) + 3(645) = 11,373 liter oxygen

Over-all daily average = 630 liters/day ≅ 3,000 kcal/day ≅ 11,900 BTU/day

Operator 2

$$(480)(0.29) + 120(0.3) + 750(0.5) + 60(1.7) + \left\{\begin{array}{l} 42 \\ 56 \\ 63 \end{array}\right\} = \left\{\begin{array}{l} 694 \text{ liters/day : 1st 9 days} \\ 708 \text{ liters/day : 10th through 15th day} \\ 715 \text{ liters/day : 16th through 18th day} \end{array}\right\}$$

Totals: 9(694) + 6(708) + 3(715) = 12,639 liters oxygen

Over-all daily average = 670 liters/day ≅ 3,200 kcal/day ≅ 12,700 BTU/day

Table 23. Estimated Oxygen Consumption per Kilogram Body Weight per Day (estimated from heart rates and body rates)

Subject	Days in the Simulator	Estimated Oxygen Consumption		Weight in Kilogram Used For Calculations	Estimated Oxygen Consumption Per Kilogram per Day	
		liters/day	kcal/day*		ℓ/kg/day	k cal/kg/day*
Operator 1	First 9 days	622	2980	77.0	8.09	38.8
	10 through 15	640	3070	78.0	8.20	39.4
	16 through 18	645	3100	75.0	8.60	41.3
Operator 2	First 9 days	694	3280	89.0	7.80	37.4
	10 through 15	708	3400	88.8	7.98	38.3
	16 through 18	715	3430	86.2	8.30	39.8

* This assumes an R.Q. of 0.82. Then 1 liter of oxygen is equivalent to 4.8 kcal of metabolic heat. (References 6, 7, 9 and 24)

Table 24. Average Maximum Heart and Respiration Rates and Their Standard Deviations for Simulation

TASK	Operator 1				Operator 2			
	HR	SD	RR	SD	HR	SD	RR	SD
Audio Balancing	71.8	4.3	16.2	2.7	75.5	5.6	15.9	2.8
Driving	76.6	3.4	14.9	1.9	75.5	4.9	15.3	2.7
Eating	75.7	6.1	14.6	2.9	77.0	6.1	14.9	2.5
Monitor	74.6	5.7	15.1	3.1	77.5	4.7	14.5	1.8
Sample Mea.	74.6	5.6	16.9	2.4	78.2	9.2	14.5	2.4
Navigation	80.4	5.4	15.6	2.1	83.9	5.2	17.8	3.2
Suit Don	109.2	6.5	27.8	4.7	114.6	7.9	26.5	1.4
Suit Doff	101.0	13.6	26.3	2.9	112.7	10.7	26.8	3.1
Sleep	56.0		12.5		61.4		13.5	
Treadmill Activity (inflated pressure suit)								
• 1.6 kmph (1 mph,) 2% grade, walk	112	---	27	---	125	---	29	---
• 4.15 kmph (2.6mph,) 4% grade, walk	148	---	32	---	155	---	34	---
• 8.0 kmph (5mph,) 4% grade, run	170	---	40	---	184	---	39	---

Table 25. Heart and Respiratory Rates Per Task As The Ratio Of The Observed Value, P, To That Obtained During Maximal Work (P_C)

TASK	Operator 1		Operator 2	
	Heart Rate P_C = 175	Respiration Rate P_C = 47	Heart Rate P_C = 182	Respiration Rate P_C = 34
Audio Balancing	0.410	0.344	0.416	0.468
Driving	0.437	0.318	0.416	0.450
Eating	0.432	0.311	0.424	0.438
Monitoring	0.426	0.321	0.426	0.426
Sample Measurement	0.426	0.360	0.430	0.426
Navigation	0.460	0.332	0.461	0.523
Suit Donning	0.625	0.592	0.630	0.780
Suit Doffing	0.578	0.556	0.620	0.788
Treadmill, pressurized walk, (2.6 mph) peak, 10 min. (4.15 kmph)	0.850	0.680	0.850	1.00
Treadmill, shirt sleeves walk, (3 mph), 10 min. (4.8 kmph)	0.780	---	0.787	---
Treadmill, shirt sleeves run, (6 mph), 2:45 min. (9.6 kmph)	1.00	1.00	1.00	1.00
Treadmill, pressurized run, (5 mph), 1 min. (8.0 kmph)	0.97	0.85	1.01	1.15

Table 26. Vehicle Cabin Habitability Ratings

Period Evaluated	Numerical Rating*	
	Operator 1	Operator 2
3 days	5	6
7 days	5	6
14 days	6	6

*See Figure 35 for numerical rating identification

Table 27. Food Item Evaluation

No.	Food Item	Operator 1	Operator 2
1	Corn Flakes		Not bad
2	Coffee	Good	Not bad
3	Bacon and Eggs	Good	Rough to get down
4	Tomato Cocktail	Good	
5	Chicken a la King	Too bland. Needs more seasoning (salt)	
6	Banana Pudding		Not bad
7	Orange Juice	Tastes all right. Poor mixing	Not bad
8	Fruit Bar	Good	Not bad
9	Hash	Good	
10	Chocolate Pudding	Tasty, poor mixing	
11	Graham Cracker Bites	Tasty, crumble, bland	Not bad
12	Lemon Drink	Good	Not bad
13	Beef Stew	Excellent - Fair	
14	Wheat Flakes	Good	
15	Scrambled Eggs	Fair	
16	Cinnamon Toast	Fair	Not bad
17	Cream of Potato Soup	Good - Excellent	
18	Sugar Cooky Bites	Good - crumbly	
19	Barbequed Beef	Fair	
20	Lemon Pudding	Excellent	Excellent
21	Fruit Bar	Good	
22	Ground Beef with Rice	Good	
23	Butterscotch Pudding	Good	
24	Bacon and Toast Bites	Fair	Not bad
25	Beef Pieces with Gravy		Not bad
26	Cherry Drink	Not good for breakfast	Not good for breakfast
27	Grape Drink		Not bad
28	Beef Barley Soup		Not bad
29	Chicken Pieces and Gravy		Not bad
30	Oat Cereal		
31	Pork with Gravy		Lousy
32	Beef Stroganoff		
33	Turkey Pieces and Gravy	Tastes like cardboard	Tastes like cardboard
34	Rice Krispies	Good	

Table 28. Subjective Rank Ordering of Tasks According to Preference

Task	Rank order (best to worst)			
	Operator 1	Operator 2	di	di^2
1. Navigation	1	1	0	0
2. Geophysical	2	2	0	0
3. Pattern Recognition	3	4	+1	1
4. Driving	4	5	+1	1
5. Audio Balancing	5	6	+1	1
6. Sample Measurement	6	3	-3	9
7. Monitoring	7	7	0	0
Totals			0	12

Rank Correlation Coefficient: $r_s = 1 - \frac{6(\Sigma di^2)}{N(N^2 - 1)}$

$r_s = 0.82$ significant at 5 percent level.

Table 29. Early LUNEX II Task Completion Times

Task Group	Approximate time to complete (hrs:min)
1. Personal time, hygiene, and housekeeping tasks	1:30
2. Eating and associated cleanup	2:55
3. Driving tasks	2:00
4. Extravehicular tasks	1:00
5. Inside scientific tasks (including navigation and charting)	4:25
6. Suit donning and doffing (including airlock pump up and pump down)	3:40
7. Buffer time period	:30
8. Sleeping	8:00
Total	24:00

Table 30. Final LUNEX II Task Completion Times

Task Group	Approximate time to complete (hrs:min)
1. Personal time, hygiene and housekeeping tasks	4:05
2. Eating and associated cleanup	3:00
3. Driving tasks	2:00
4. Extravehicular tasks	1:10
5. Inside scientific tasks (including navigation and charting)	3:40
6. Suit donning and doffing (including airlock pump up and pump down and crew exchange)	1:35
7. Buffer time period	:30
8. Sleeping	8:00
Total	24:00

FIGURES

Figure 1. Side View of LUNEX II Showing TV Monitor and Task Time Rack

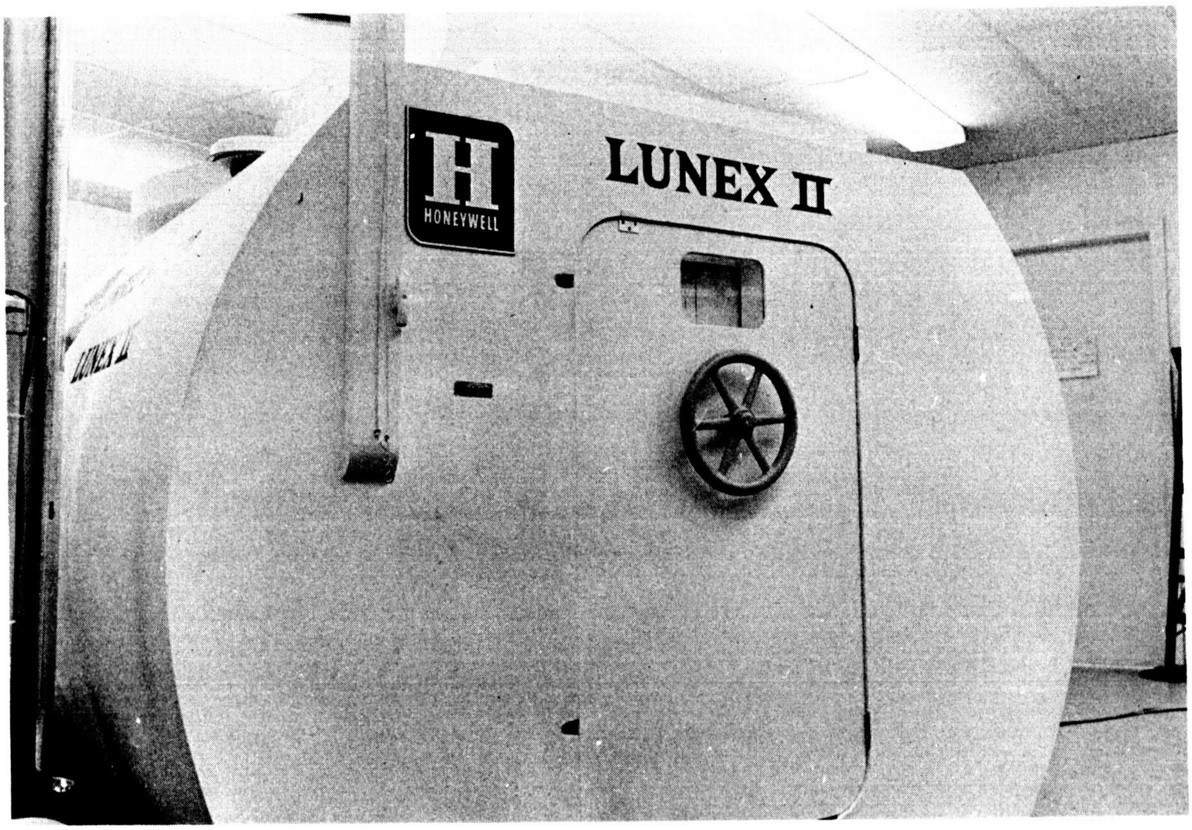


Figure 2. Front View of LUNEX II

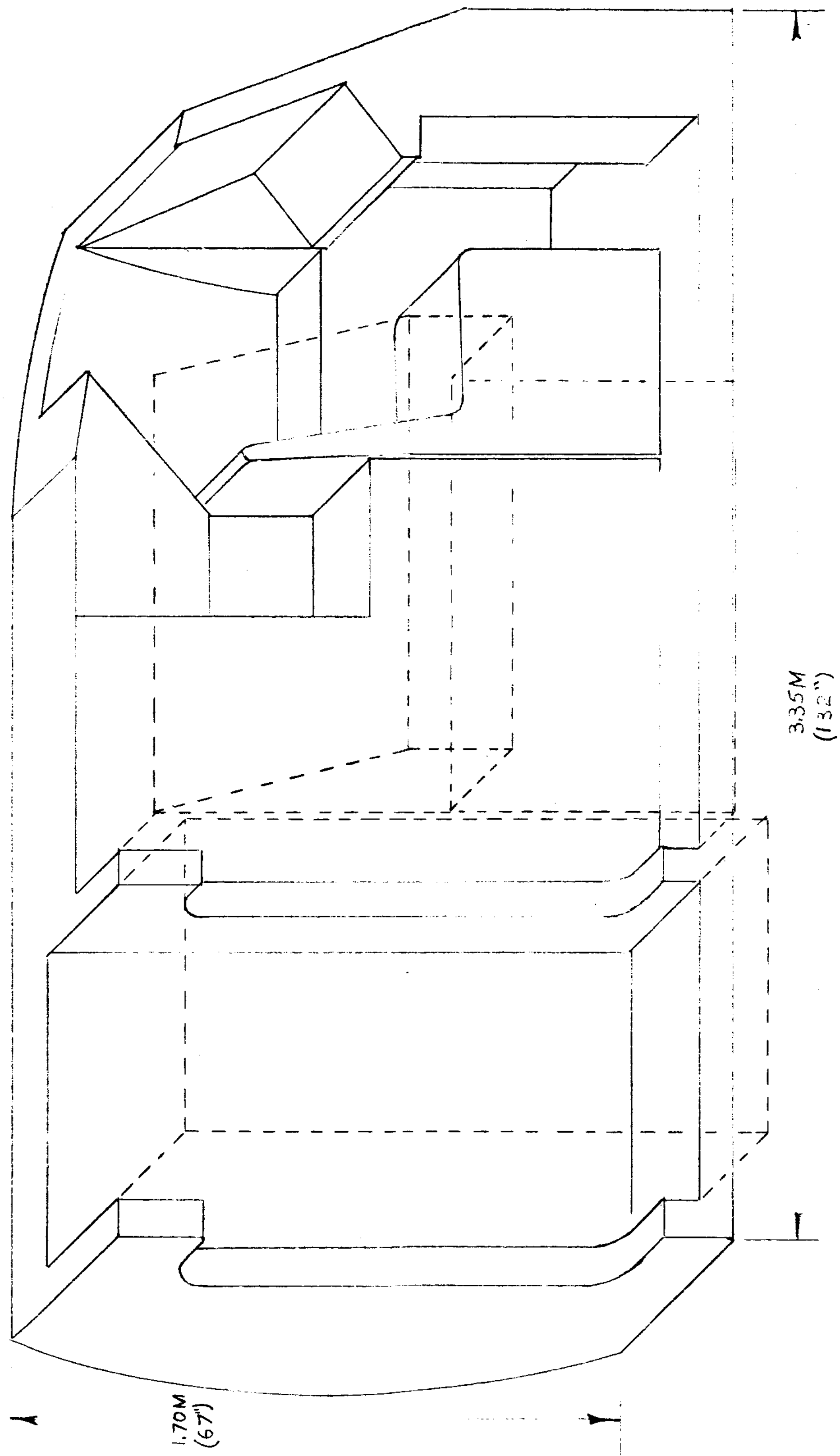


Figure 3. Sectional View of LUNEX II

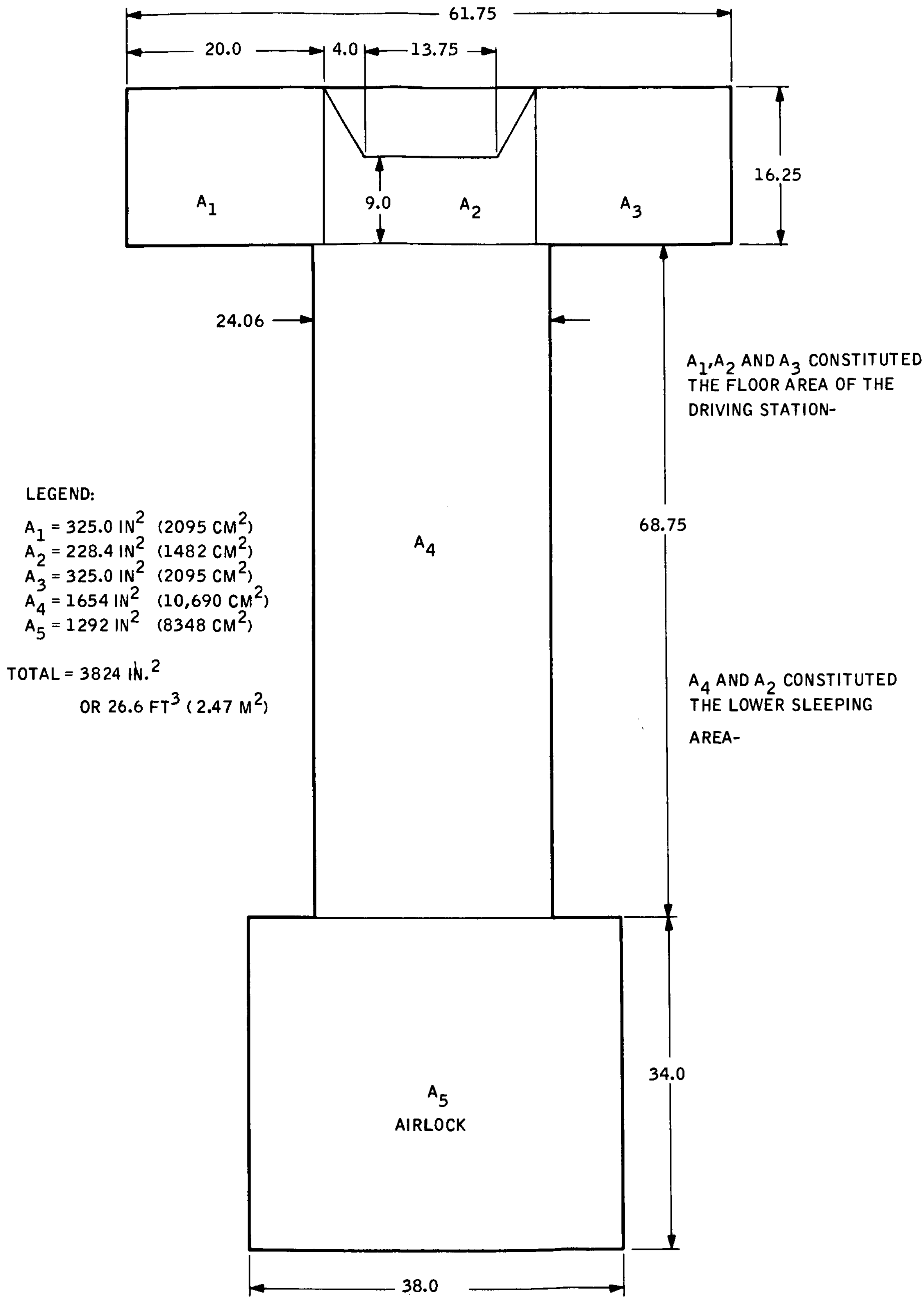
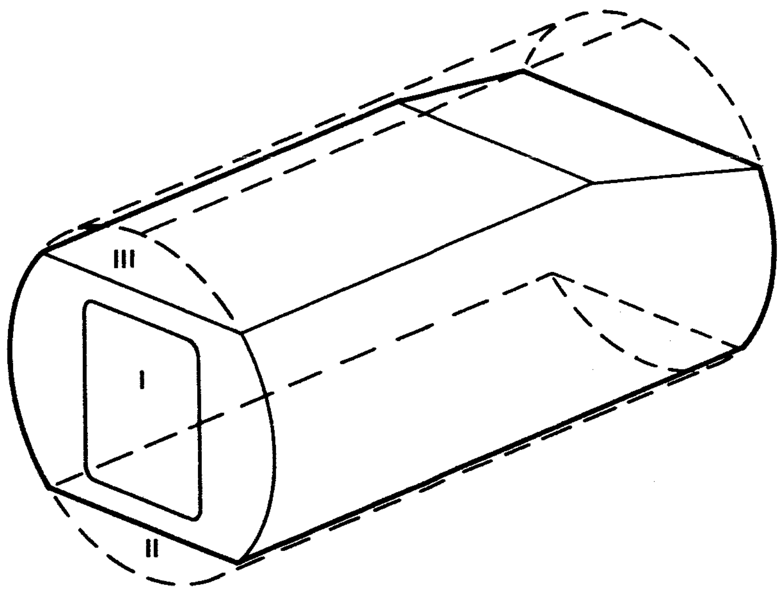


Figure 4. LUNEX II Floor Area



VOLUME ELEMENT	VOLUME CUBIC FEET	VOLUME CUBIC METERS
I (LUNEX II)	303.6	8.52
II VEHICLE SYSTEM EQUIPMENT AND	57.2	1.62
III ACCESSORY GEAR	32.1	0.91
TOTAL	392.9	11.05

Figure 5. Volume Available in a Cylindrical Vehicle of the Type Simulated

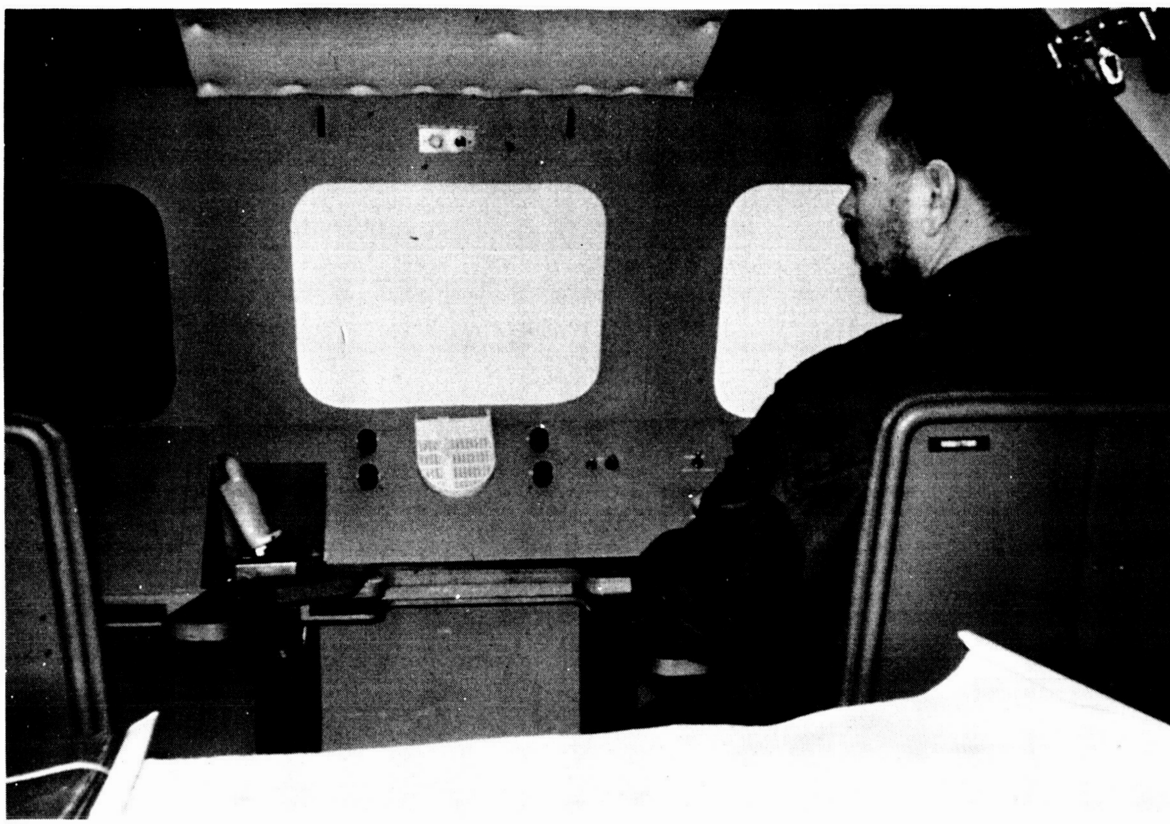


Figure 6. LUNEX II Driving Station (the center-aisle breadboard is extended with the subjects' navigation map in view)

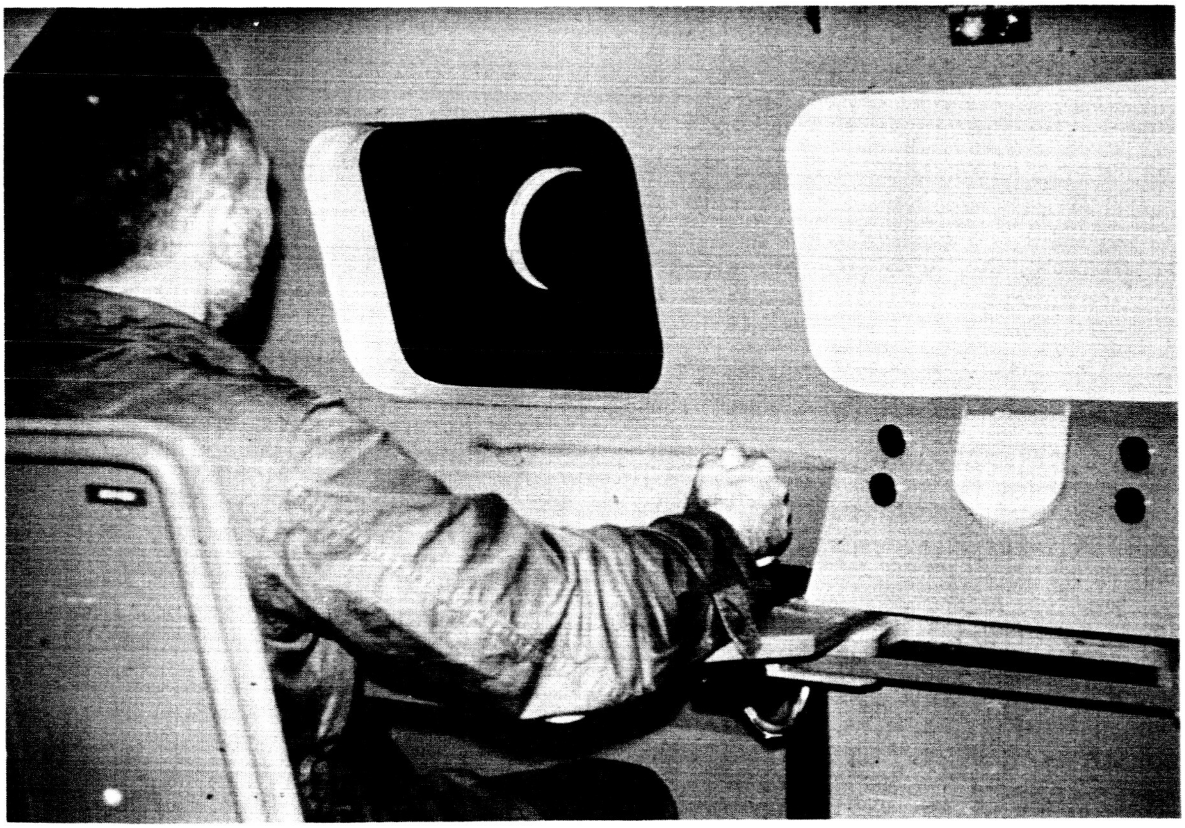


Figure 7. LUNEX II Driving Area

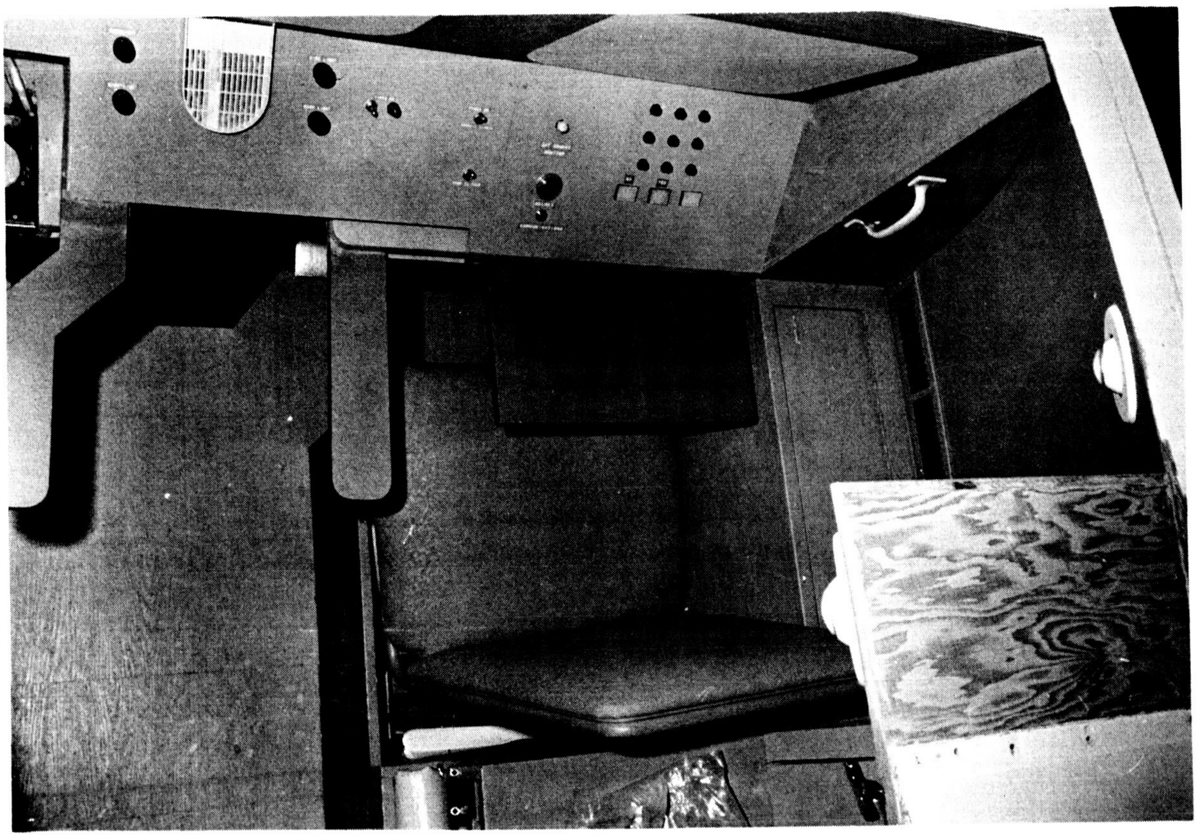


Figure 8. LUNEX II Monitoring Area (showing the nine-light matrix with its associated response buttons, the driver's off-time monitoring light and response button, a push-to-talk switch, and the four potentiometers regulating the driving station lights; the arm rests and writing board are extended; the monitor's chair is in its forward position)

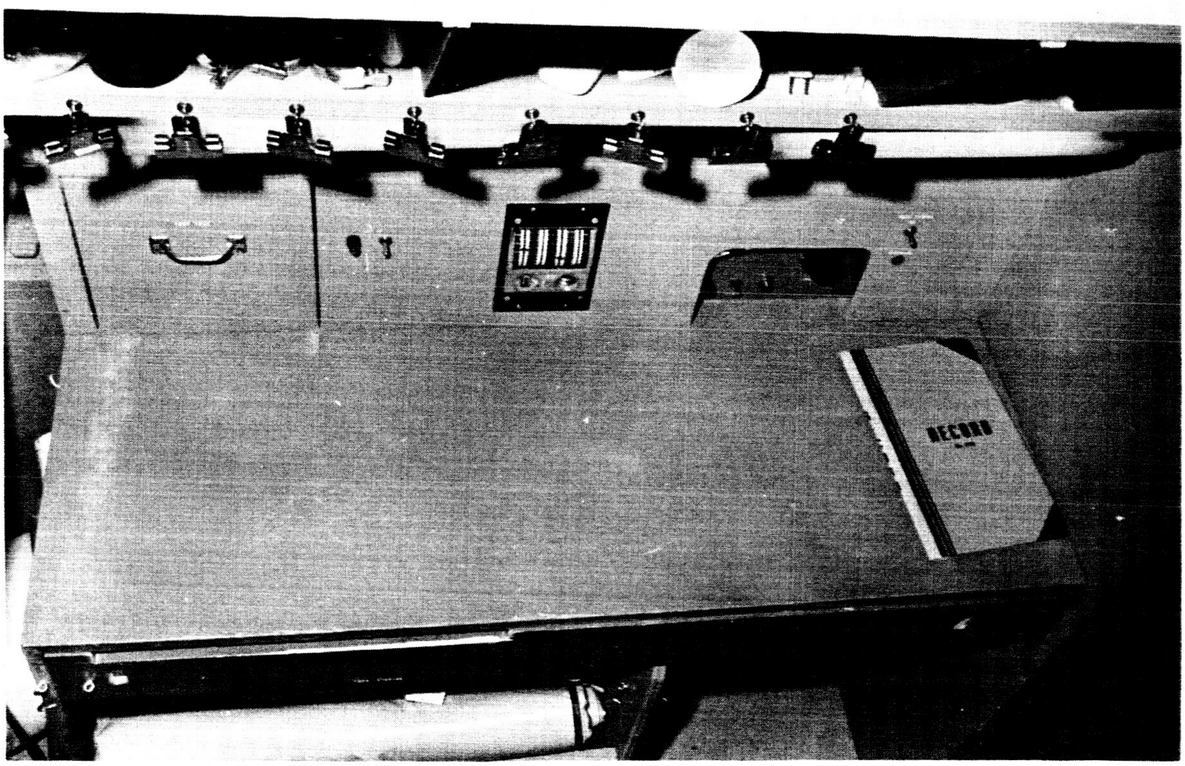


Figure 9. LUNEX II Work Station (showing the pass box, Gimbal Position Indicator, and audio-balancing work area; the clips were used to hold food bags during rehydration)

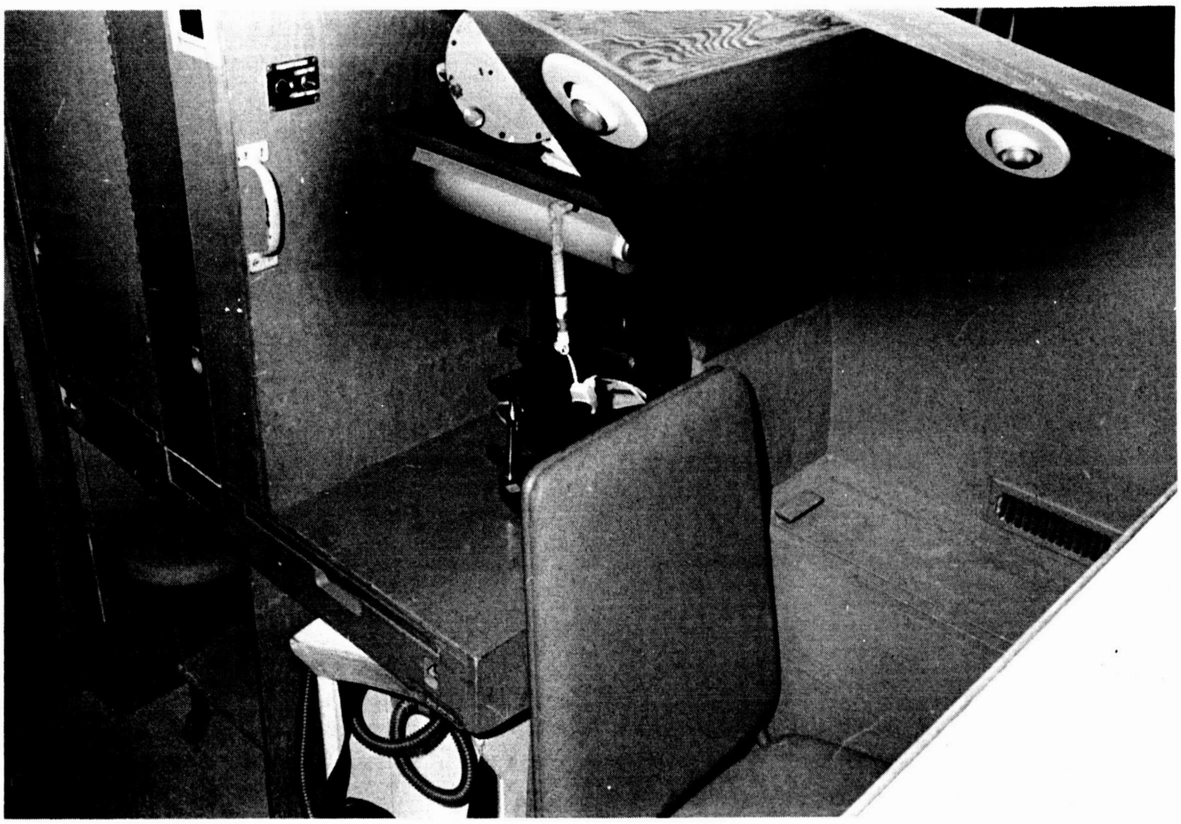


Figure 10. LUNEX II Work Station (showing the microscope storage and work area directly behind the driver's chair)

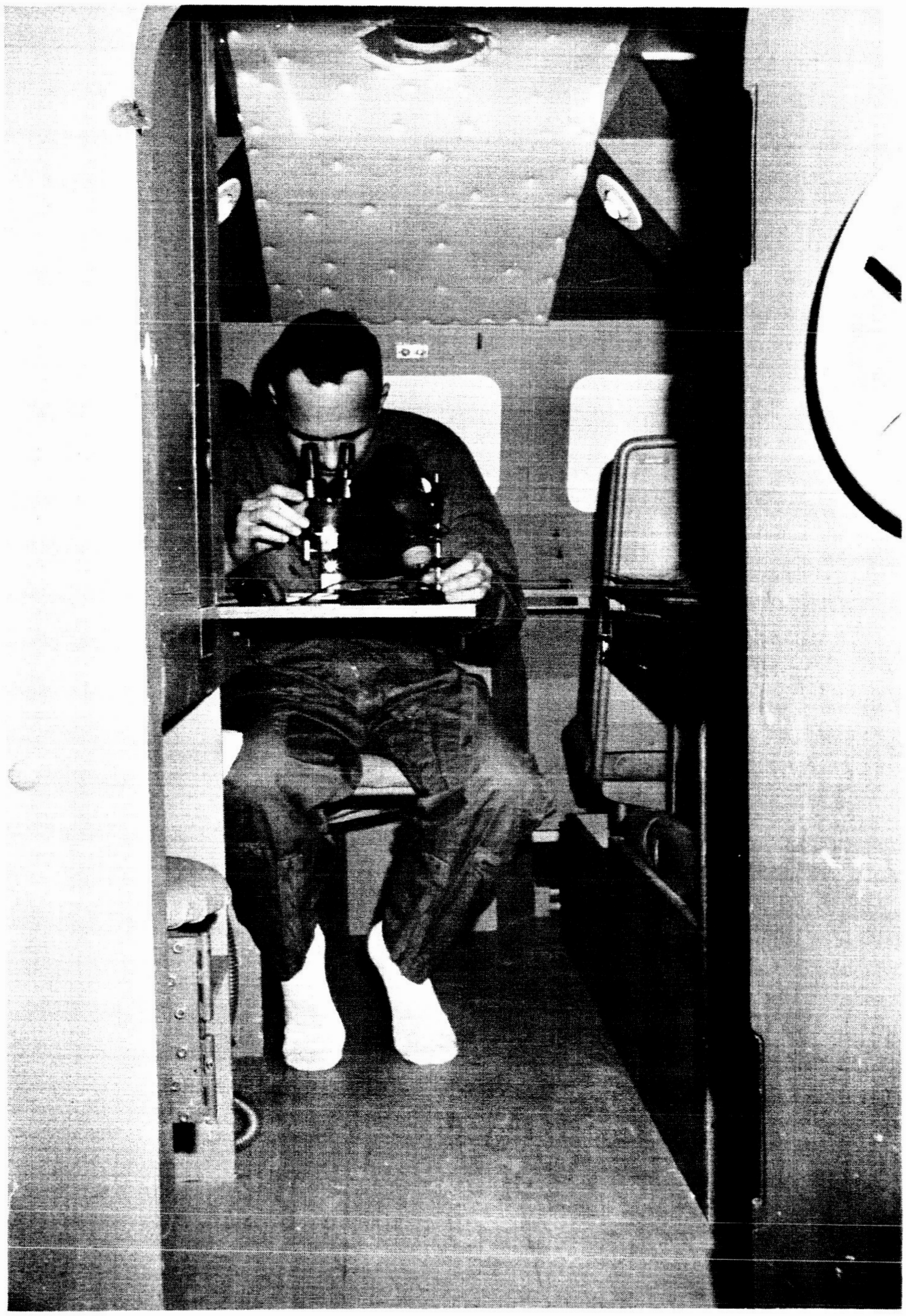


Figure 11. View from LUNEX II Airlock (showing center stowable work-space board partially extended for a microscope task; the driver's chair has been pivoted for use in the workspace area)

Figure 12. Center-Aisle Seat in an Extended Position

Figure 13. Sleeping Quarters (normal sleeping arrangement with upper bunk fully extended - as viewed from airlock)

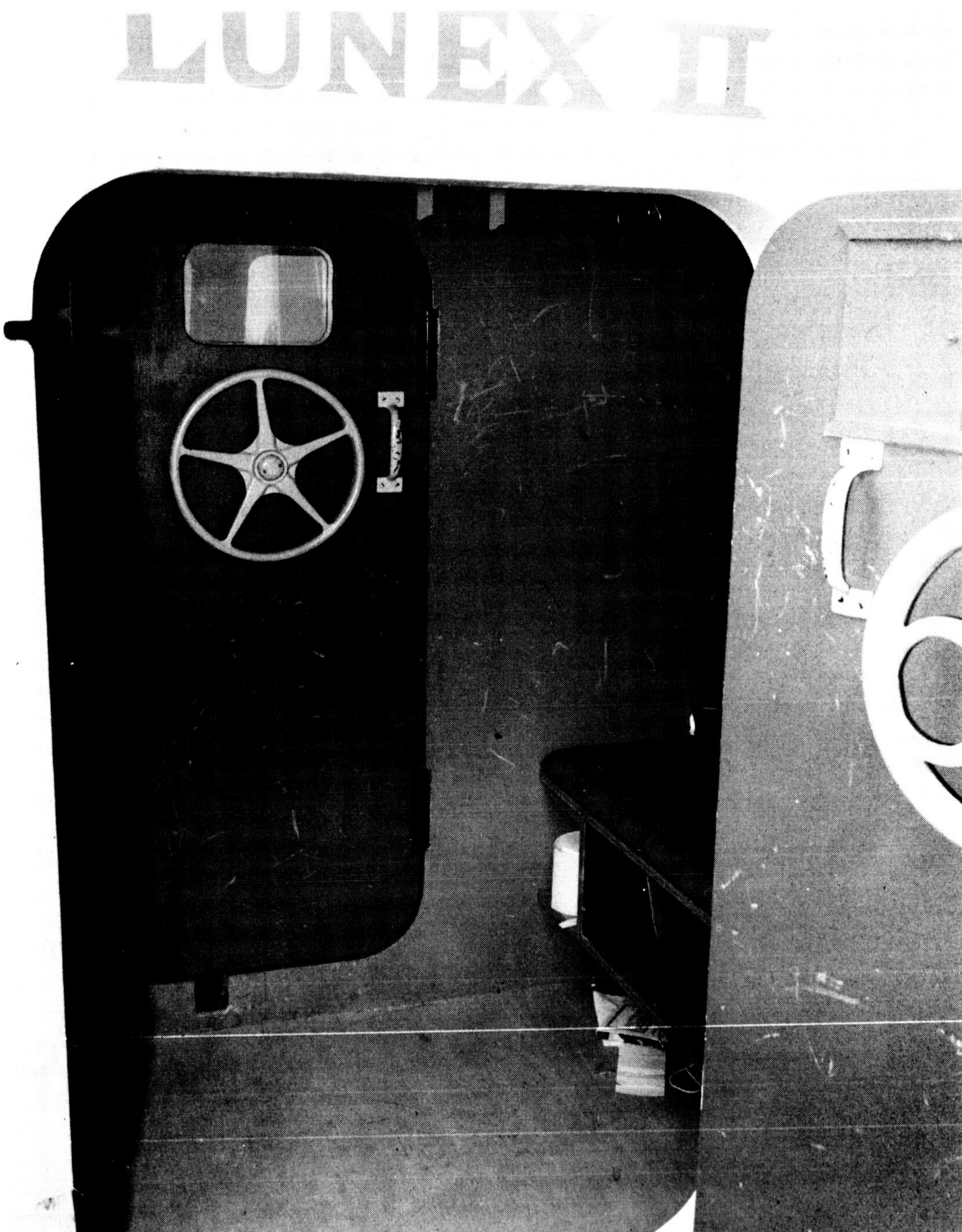


Figure 14. Airlock Viewed Through Outer Hatch

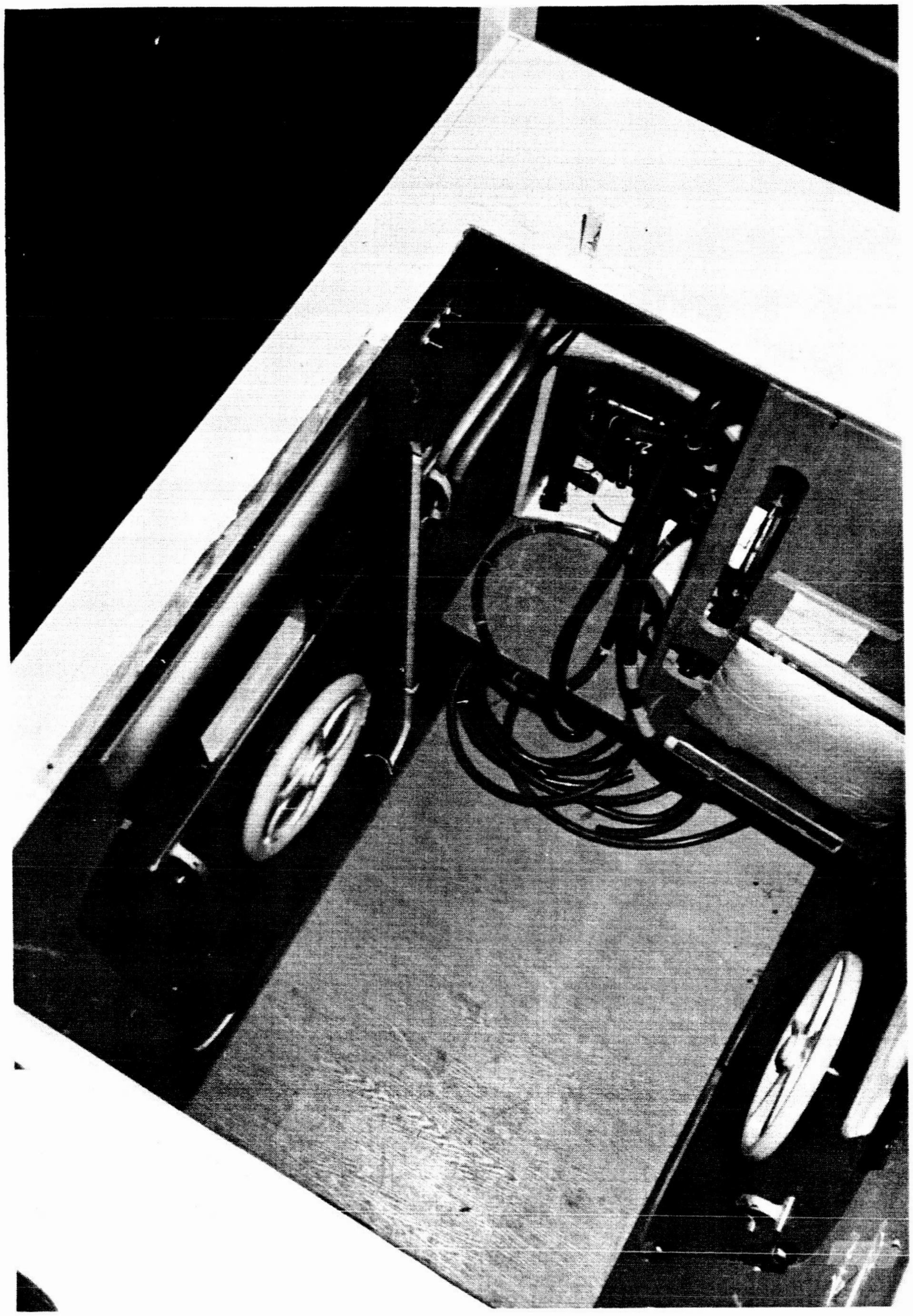


Figure 15. Airlock Viewed from Top - Both Hatches Secured

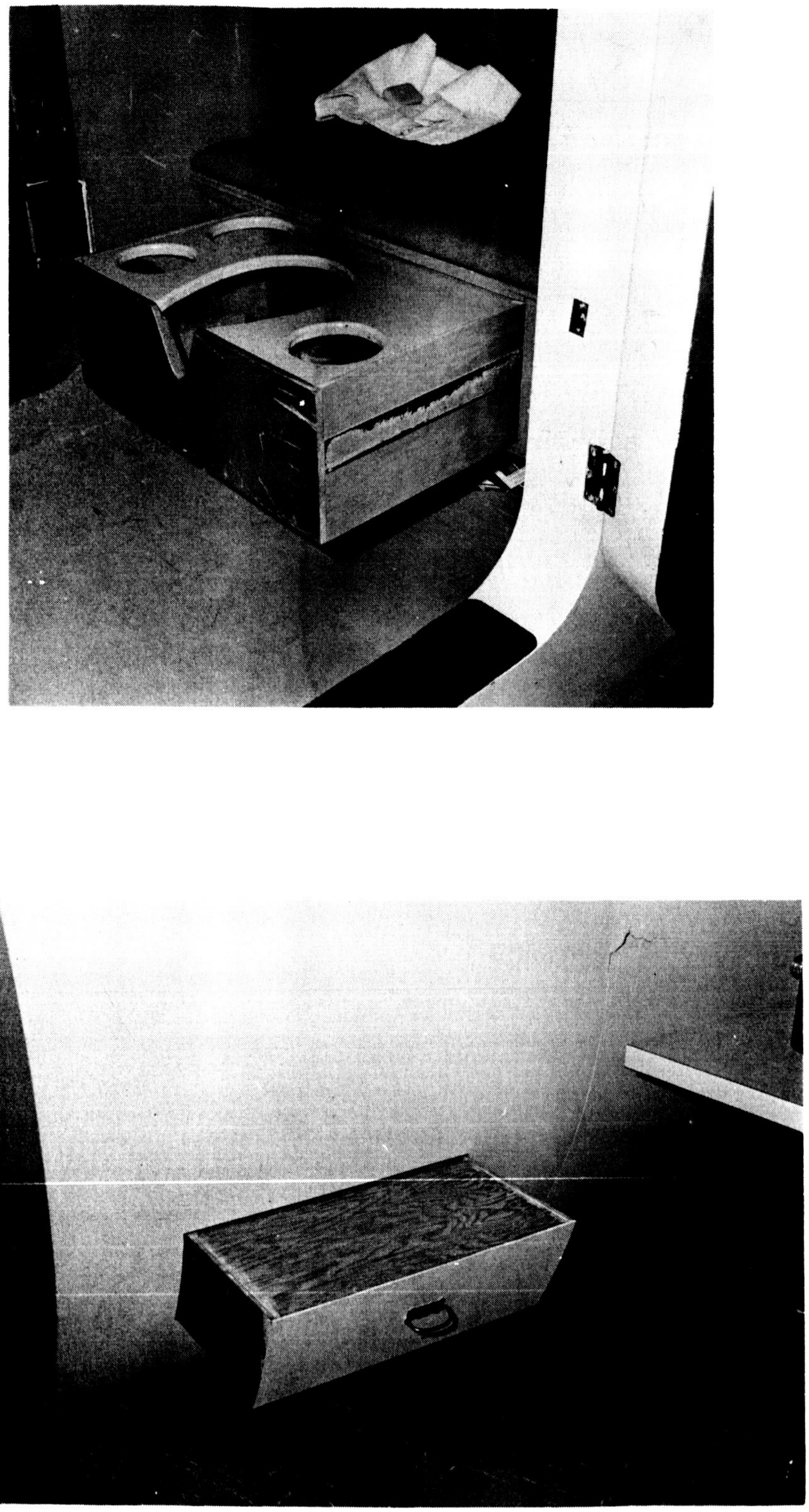


Figure 16. Toilet Facilities (view 'a' shows toilet extended into airlock; small holes contain urine bottles; view 'b' shows toilet in partly withdrawn position; further withdrawal permitted experimenters to collect urine and fecal samples)

Day No. 1	Dry Wt. (gms)	Water Needed (ml)	Calorie	Protein (gms)	Fat (gms)
Meal No. 1					
Corn Flakes	50	175	220	4.55	7.0
Coffee	2	220	5		
Bacon and Eggs	50	75	310	17.6	23.85
Tomato Cocktail	33	204	70	2.4	.46
Total	135	674	605	24.55	31.31
Meal No. 2					
Chicken ala King	50	150	233	22.72	11.82
Banana Pudding	45	90	198	.65	5.35
Orange Juice	50	177	187	1.22	.30
Coffee	2	220	5		
Fruit Bar	42.6		180	3.10	12.40
Total	189.6	637	803	27.69	29.87
Meal No. 3					
Hash	50	220	225	8.9	8.4
Coffee	2	220	5		
Chocolate Pudding	60	120	265	2.2	6.65
Graham Cracker Bites	50		220	4.55	9.40
Total	162	560	715	15.65	24.45
Meal No. 4					
Lemon Drink	40	240	154		
Beef Stew	100	300	483	27.76	27.18
Total	140	540	637	27.76	27.18

Figure 17. LUNEX II Simulator Menu (5-day 20-meal cycle - approximately 2800 calories per day)*

* The calorie content of the diet was estimated by the Pillsbury Company according to the U.S. Agricultural Handbook on the composition of foods (Ref. 32).

Day No. 2

Meal No. 1	Dry Wt. (gms)	Water Needed (ml)	Calories	Protein (gms)	Fat (gms)
Wheat Flakes	50	175	220	5.25	7.25
Coffee	2	220	5		
Scrambled Eggs	50	100	297	19.9	21.33
Orange Juice	50	177	187	1.22	.30
Cinnamon Toast	20		85	2.14	1.76
Total	172	562	794	28.51	30.64
Meal No. 2					
Lemon Drink	40	240	154		
Cream of Potato Soup	50	210	225	8.9	9.25
Sugar Cookie Bites	50		240	4.65	10.65
Total	140	450	619	13.55	19.90
Meal No. 3					
Coffee	2	220	5		
Barbecued Beef	50	132	287	14.2	20.85
Lemon Pudding	50	50	198	10.1	5.3
Fruit Bar	42.6		180	3.1	12.4
Total	144.6	402	670	27.4	38.55
Meal No. 4					
Ground Beef w/Rice	50	100	296	15.4	21.75
Coffee	2	220	5		
Butterscotch Pudding	45	90	198	.65	5.35
Sugar Cookie Bites	50		239	4.65	10.65
Total	147	410	738	20.7	37.75

Figure 17. LUNEX II Simulator Menu (continued) (5-day 20-meal cycle - approximately 2800 calories per day)

Day No. 3

Meal No. 1	Dry Wt. (gms)	Water Needed (ml)	Calories	Protein (gms)	Fat (gms)
Corn Flakes	50	175	220	4.55	7.00
Orange Juice	50	177	187	1.22	.30
Bacon and Toast Bites	50		225	8.20	14.45
Total	150	352	632	13.97	21.75
Meal No. 2					
Beef Pieces w/Gravy	75	110	372	34.32	16.19
Coffee	2	220	5		
Cherry Drink	40	210	154		
Banana Pudding	45	90	198	.65	5.35
Total	162	630	729	34.97	21.54
Meal No. 3					
Grape Drink	40	240	154		
Beef Barley Soup	50	275	196	8.18	8.06
Graham Cracker Bites	50		220	4.55	9.40
Cinnamon Toast	20		85	2.14	1.76
Total	160	515	655	14.87	19.92
Meal No. 4					
Chicken Pieces in Gravy	50	75	261	23.69	13.98
Tomato Cocktail	23	204	70	2.40	.46
Lemon Drink	40	240	154		
Cinnamon Toast	20		85	2.14	1.76
Fruit Bar	42.6		180	3.10	12.40
Total	175.6	519	750	31.33	28.6

Figure 17. LUNEX II Simulator Menu (continued)
(5-day 20-meal cycle - approximately 2800 calories per day)

Day No. 4

Meal No. 1	Dry Wt. (gms)	Water Needed (ml)	Calories	Protein (gms)	Fat (gms)
Oat Cereal	50	175	220	6.1	8.7
Cherry Drink	40	240	154		
Orange Juice	50	177	187	1.22	.3
Cinnamon Toast	20		85	2.14	1.76
Total	160	592	646	9.46	10.76
Meal No. 2					
Coffee	2	220	5		
Pork w/Gravy	50	75	272	38.66	33.82
Lemon Pudding	50	50	198	10.10	5.30
Fruit Bar	42.6		180	3.10	12.40
Total	144.6	345	655	51.86	51.52
Meal No. 3					
Coffee	2	220	5		
Beef Stroganoff	75	200	425	19.35	30.15
Tomato Cocktail	23	204	70	2.4	.46
Sugar Cookie Bites	50		239	4.65	10.65
Total	150	624	739	26.4	41.26
Meal No. 4					
Turkey Pieces and Gravy	75	115	390	35.53	20.97
Coffee	2	220	5		
Lemon Drink	40	210	154		
Chocolate Pudding	60	120	265	2.2	6.65
Total	177	665	814	37.73	27.62

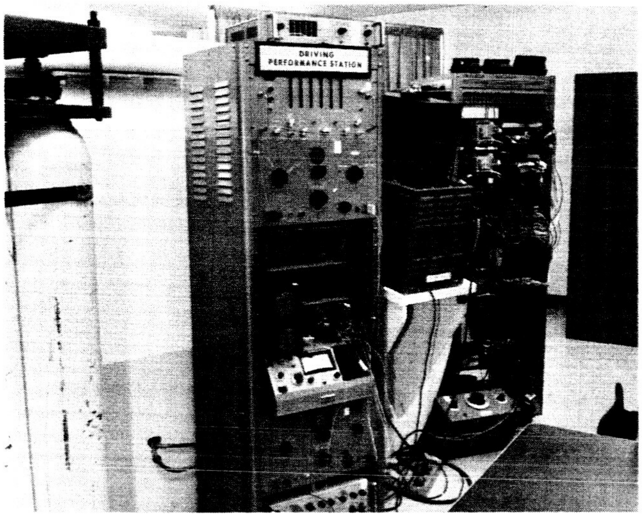
Figure 17. LUNEX II Simulator Menu (Concluded)
(5-day 20-meal cycle - approximately 2800 calories per day)

Day No. 5

Meal No. 1	Dry Wt. (gms)	Water Needed (ml)	Calories	Protein (gms)	Fat (gms)
Rice Krispies	50	175	225	4.00	7.00
Coffee	2	220	5		
Bacon and Eggs	50	75	310	17.6	23.85
Tomato Cocktail	23	204	70	2.4	.46
Total	125	674	610	24.0	31.31
Meal No. 2					
Grape Drink	40	240	154		
Cream of Potato Soup	50	210	225	8.90	9.25
Fruit Bar	42.6		180	3.10	12.46
Sugar Cookie Bites	50		240	4.65	10.65
Total	182.6	450	799	16.65	32.36
Meal No. 3					
Chicken Pieces in Gravy	50	75	261	23.69	13.98
Coffee	2	220	5		
Lemon Drink	40	240	154		
Lemon Pudding	50	50	198	10.1	5.3
Cinnamon Toast	20		85	2.14	1.76
Total	162	585	703	35.93	21.04
Meal No. 4					
Beef Pieces and Gravy	75	110	372	34.32	16.19
Orange Juice	50	177	187	1.22	.30
Coffee	2	220	5		
Butterscotch Pudding	45	90	198	.65	5.35
Total	172	597	762	36.19	21.84

Figure 17. LUNEX II Simulator Menu (Concluded)
(5 day 20 meal cycle - approximately
2800 calories per day)

Figure 18. Normal Food Preparation Positions (subject on left is putting a measured amount of water in a food container; center-aisle workspace board is extended)



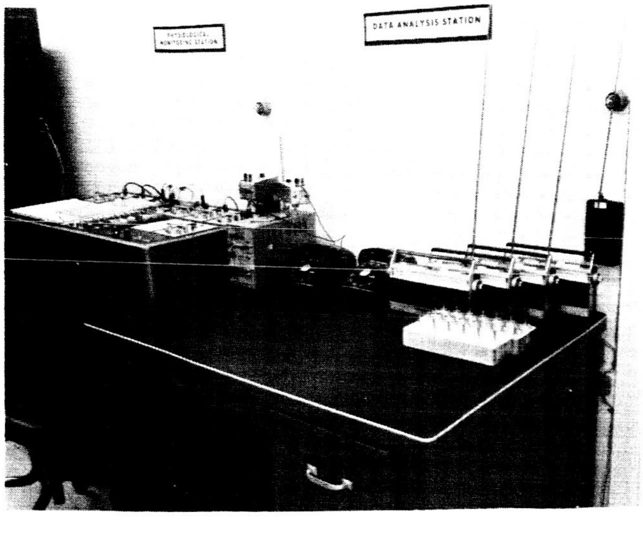


Figure 19. Experimenters' Task Equipment Stations

Figure 20. Typical View Through Television Monitor (subjects are in vented-suit condition following extravehicular activity)

Figure 21. Extravehicular Treadmill Activity

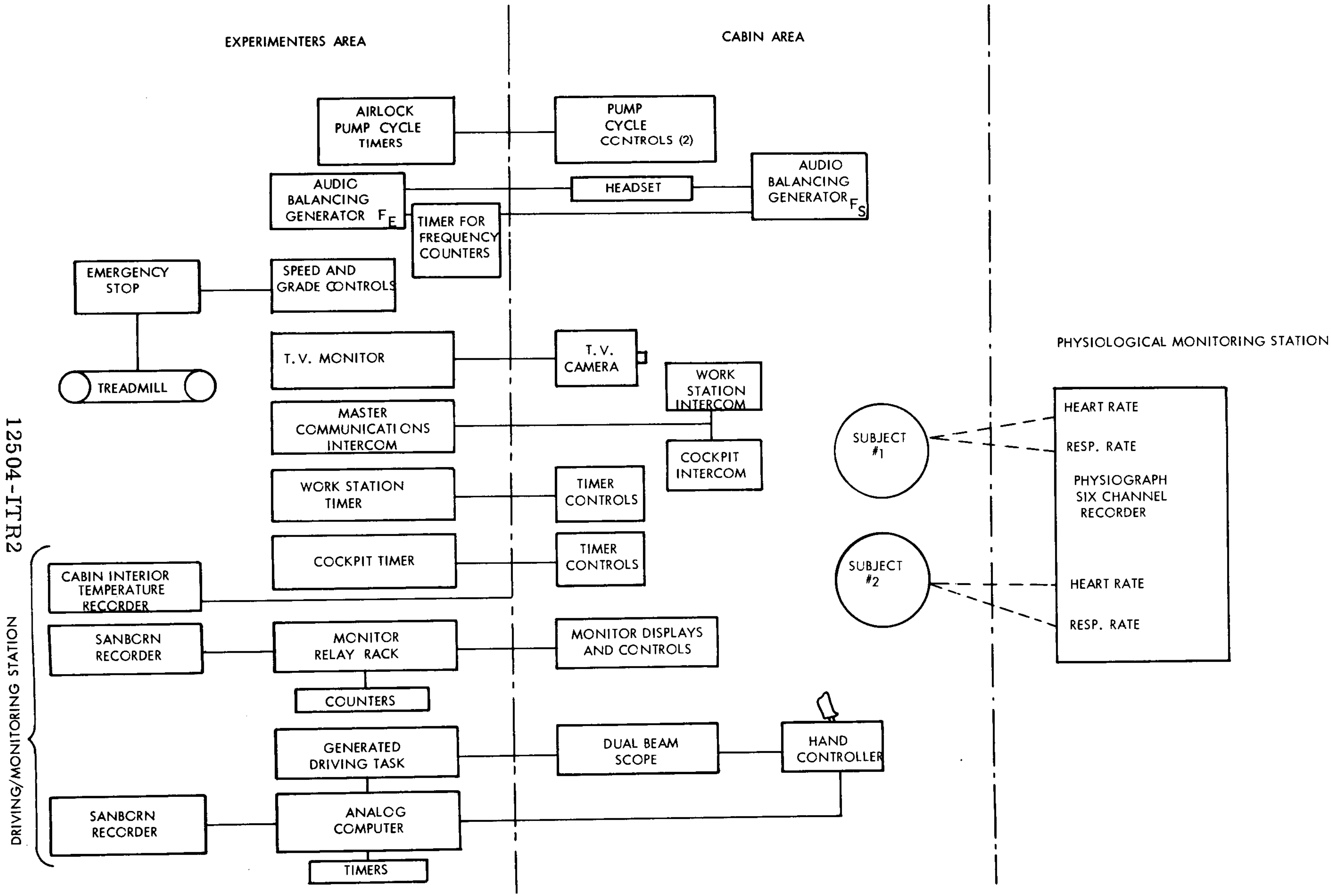


Figure 22. Interrelationship of Simulation Support Equipment

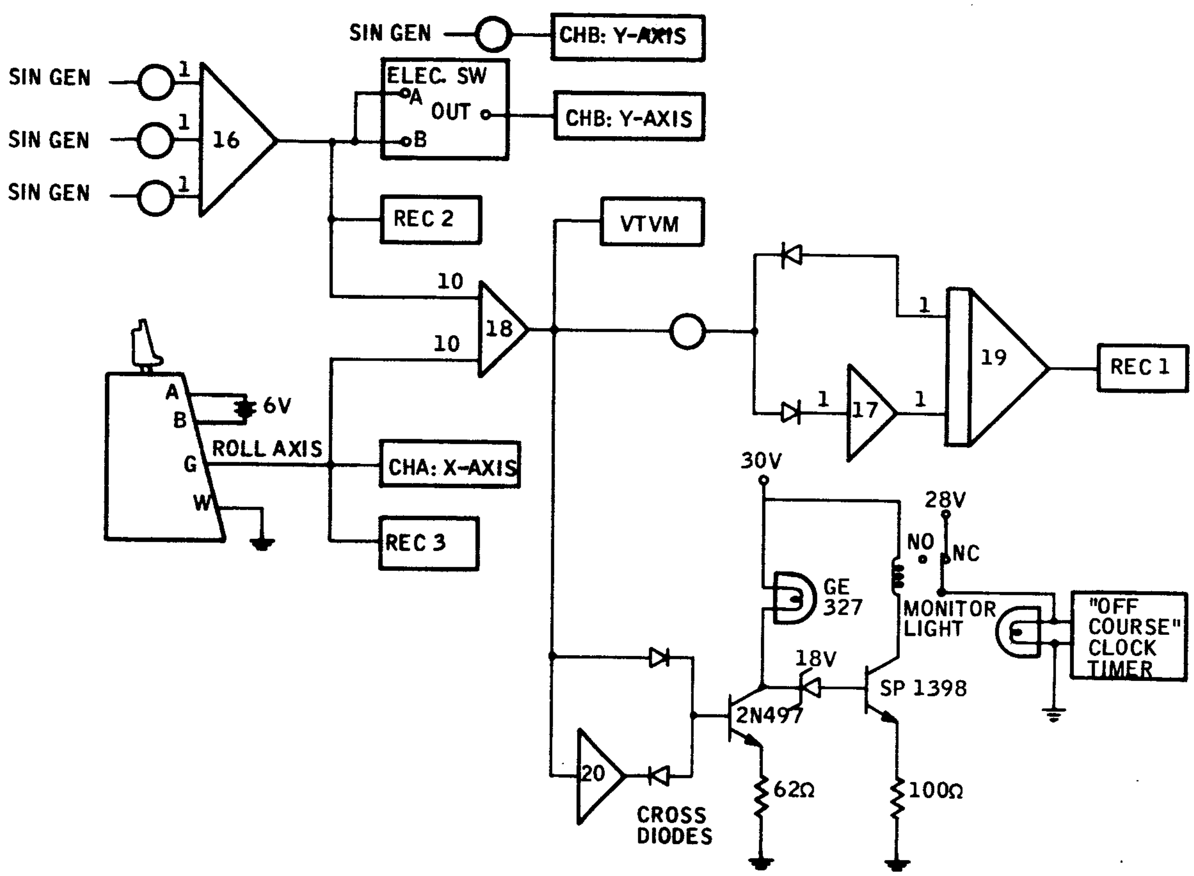


Figure 23. Driving Task Schematic

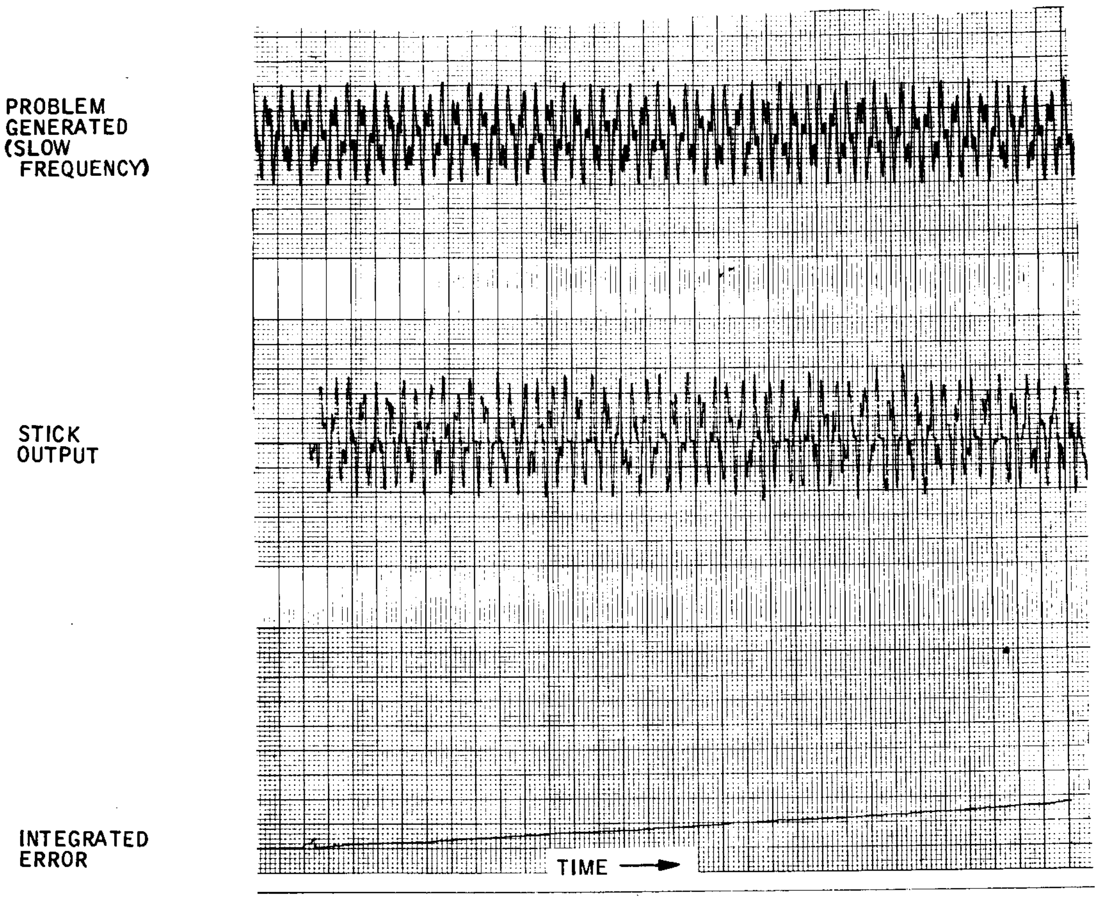


Figure 24. Recorded Output of the Slow-Frequency Driving Problem

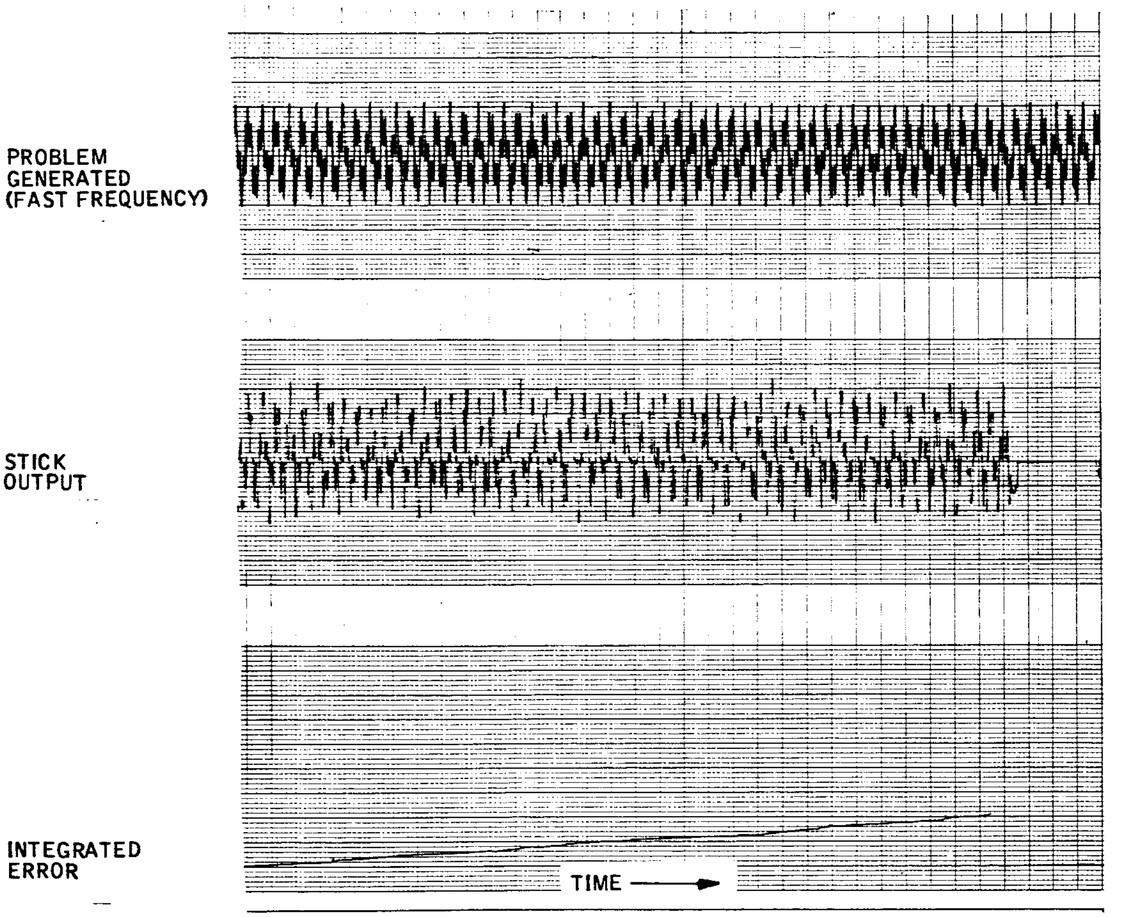


Figure 25. Recorded Output of the Fast-Frequency Driving Problem

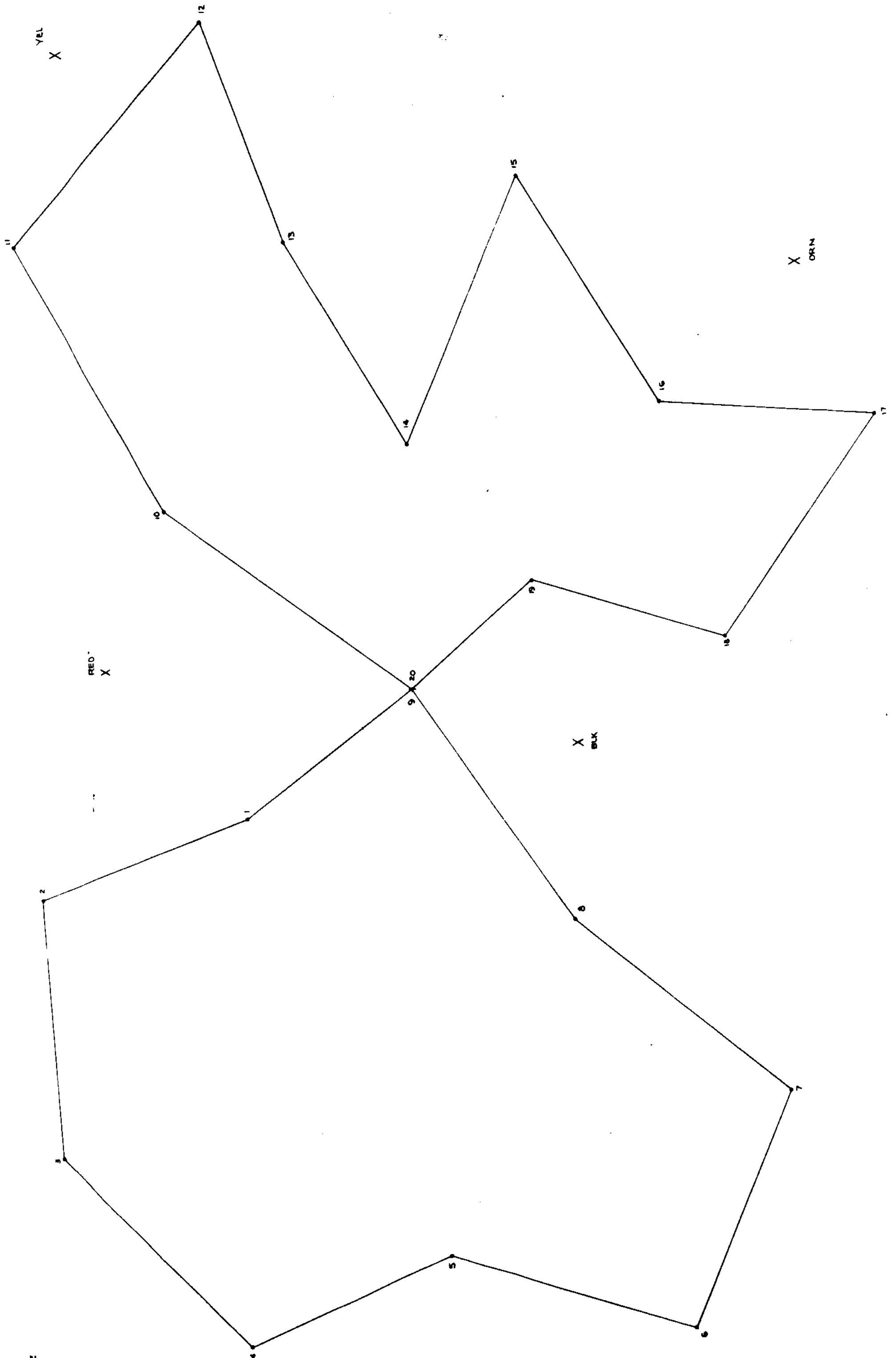


Figure 26. Navigation Map Provided to Subjects

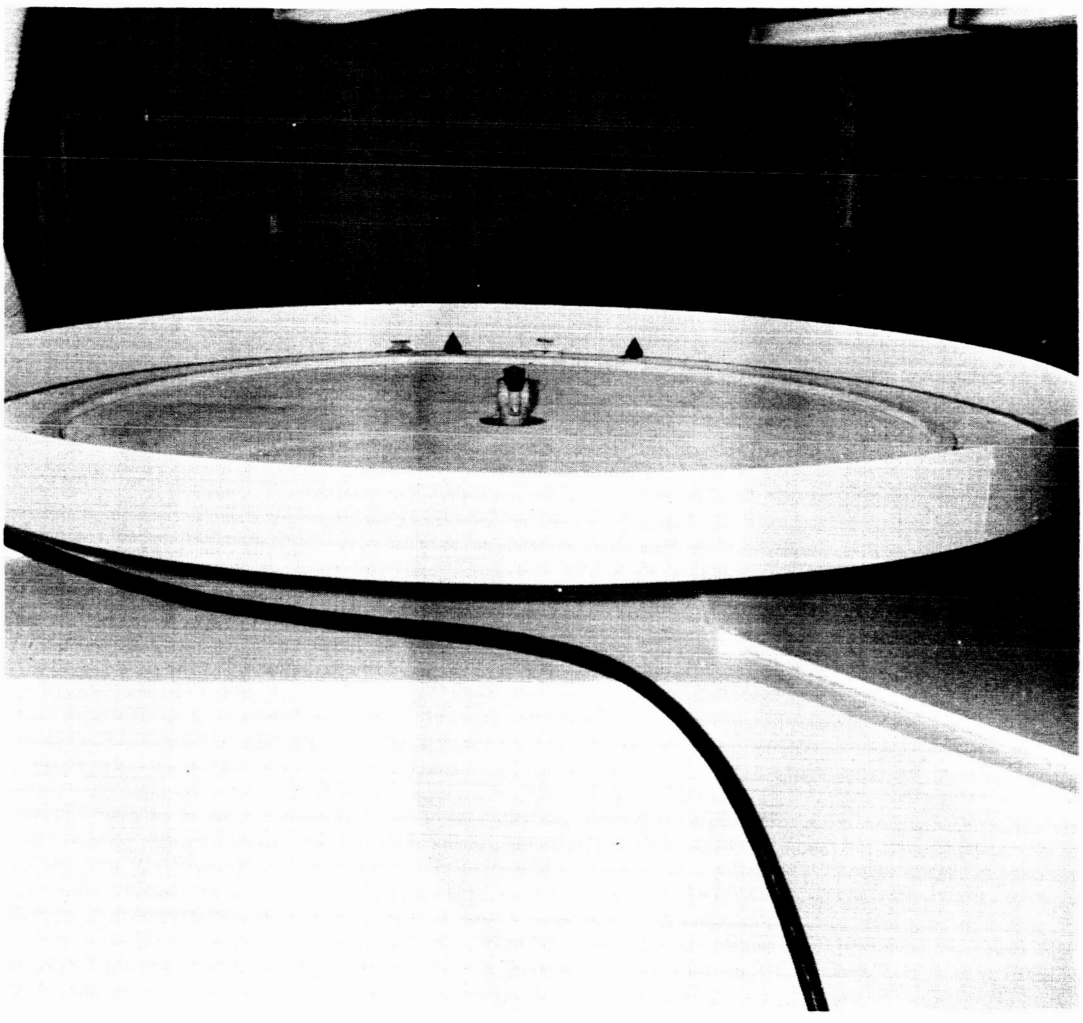


Figure 27. Navigation Task (large scribed disc with triangular "lunar mountains" on its rim is shown with the periscope in position for navigation sighting)

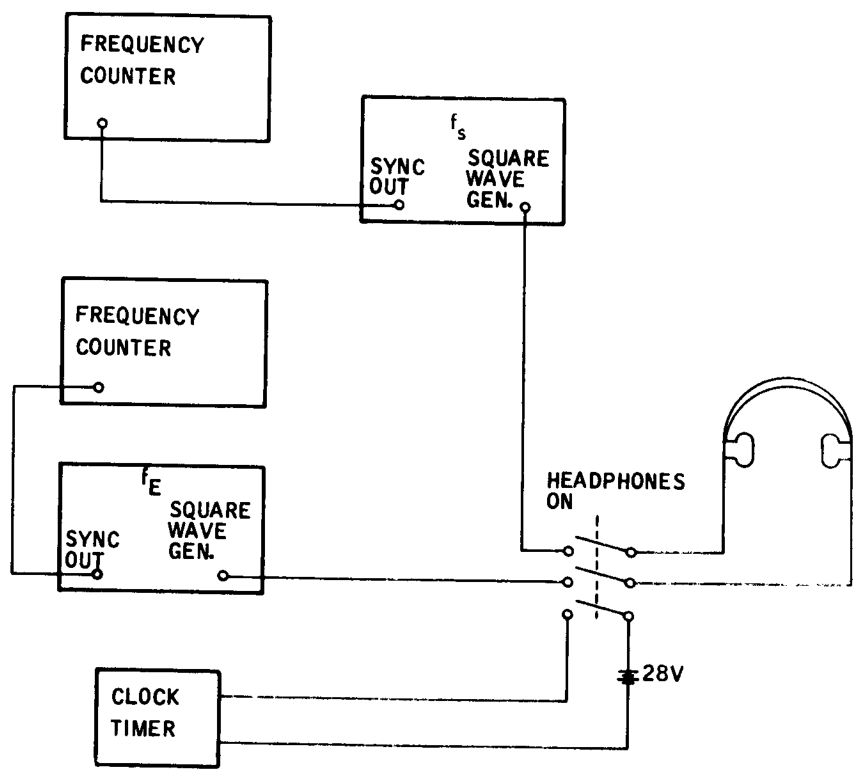


Figure 28. Audio-Balancing Task Schematic

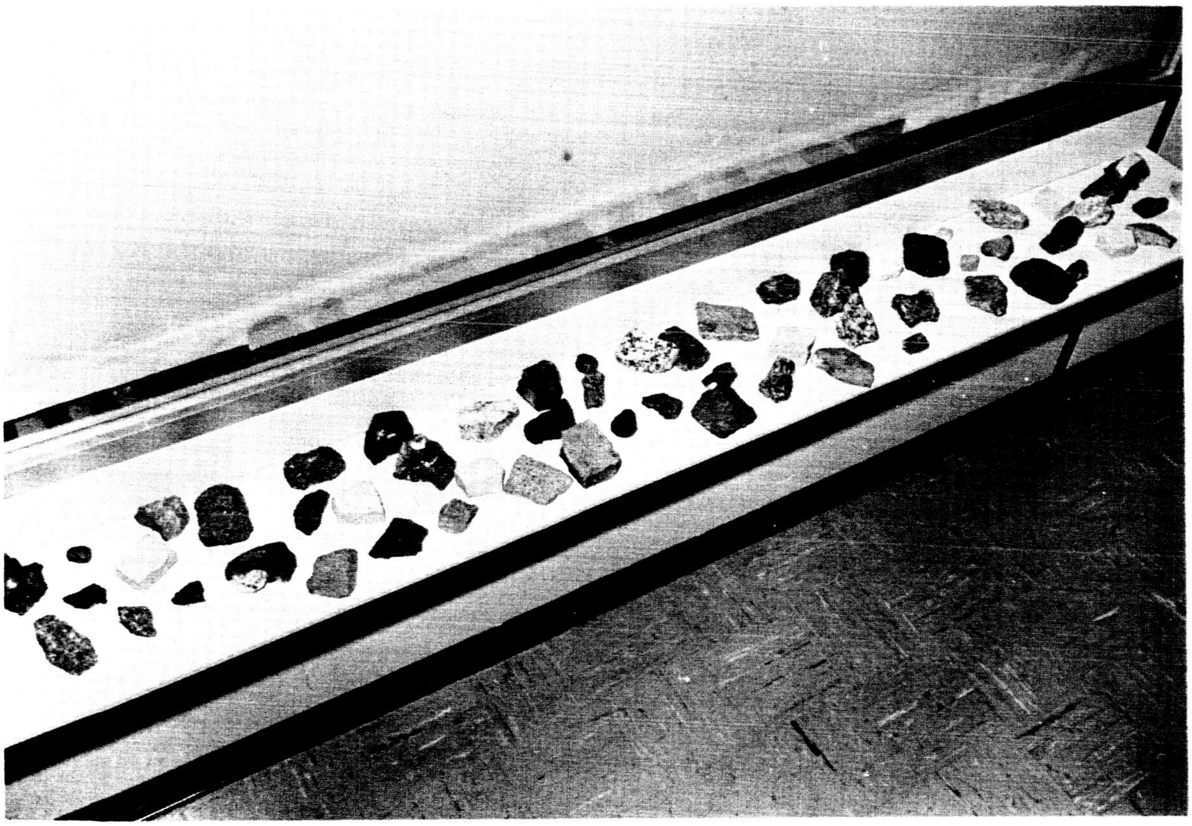


Figure 29. Rock Samples Collected During Extravehicular Activities

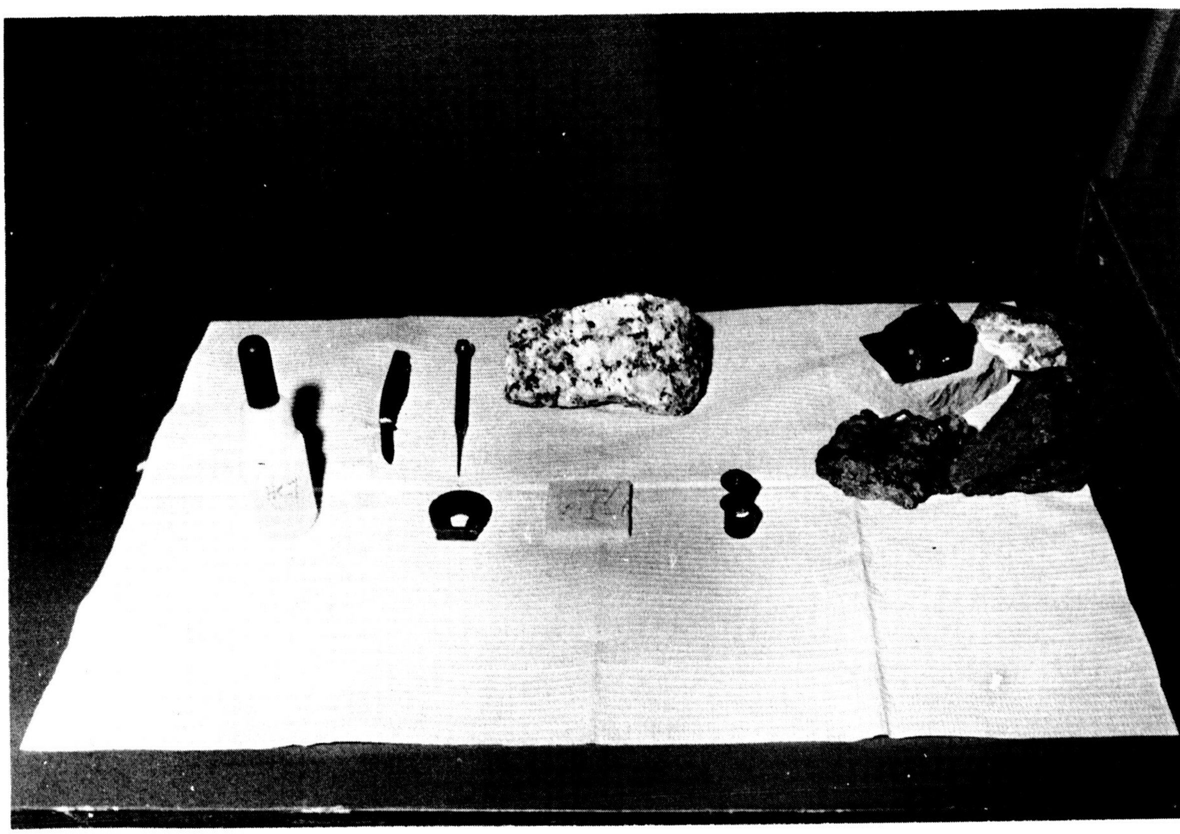


Figure 30. Rock Analysis Equipment

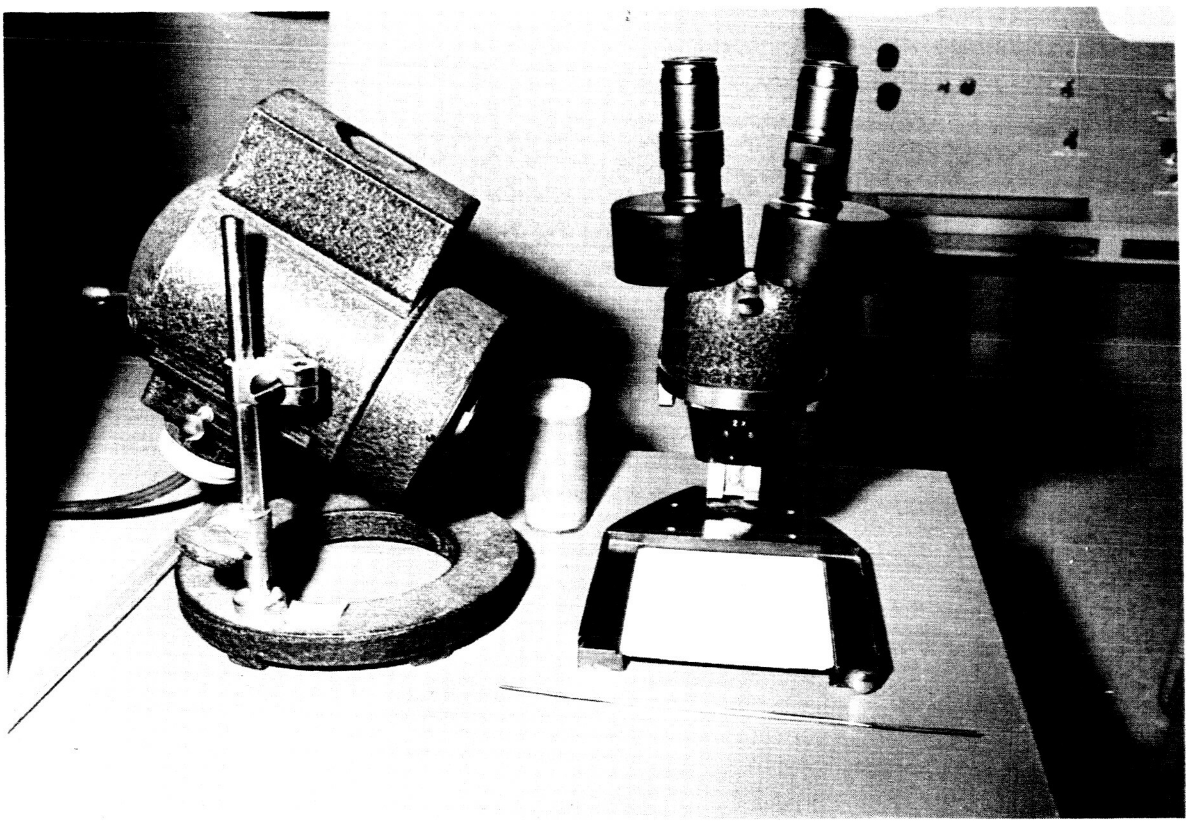


Figure 31. Binocular Microscope and Mineral Grains Used in Geophysical Point Count Task

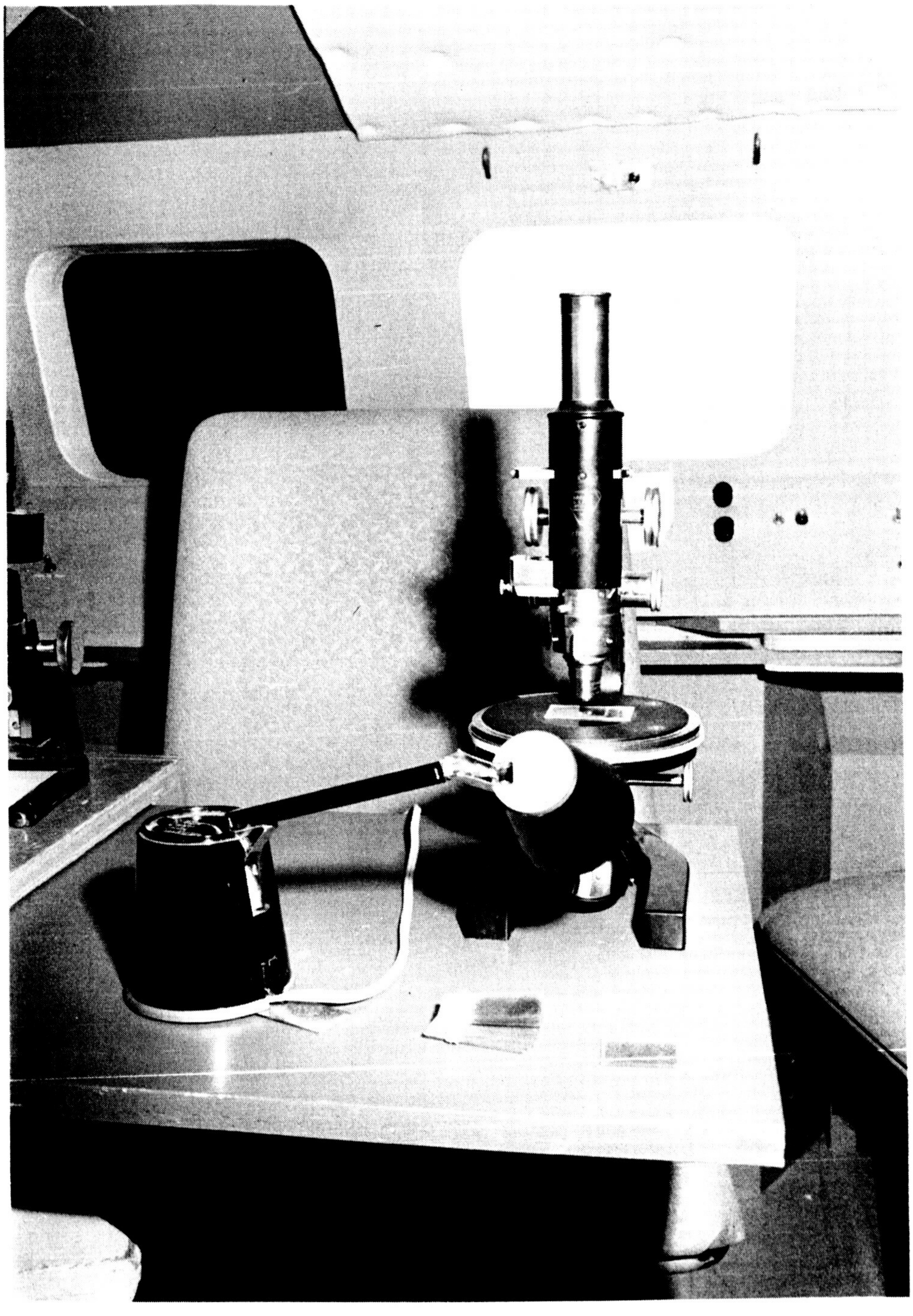


Figure 32. Polarizing Microscope and Petrographic Slides

ROCK SAMPLE ANALYSIS

From the samples outside the ship recover 20 by inspection and take these into the ship for final testing.

The rock samples must be classified with the aid of the accompanying table

Materials: Twenty samples

Instruments: Hand lens, streak plate, acid bottle, knife, magnet

Problem: Collect (i.e., retain) as many categories of rocks as possible but not two from any category.

Rock Chart

1. Granite coarse grained, light colored, contains quartz N.R.*	2. Rhyolite light colored, fine-grained equivalent of Granite, may have some large quartz grains, N.R.*
3. Obsidian volcanic glass, dark colored, white streak, knife will not scratch. N.R.*	4. Gabbro coarse grained, dark colored, may contain magnetite N.R.*
5. Basalt dark colored, fine grained, equivalent of Gabbro N.R.*	6. Sulfide brass yellow or steel gray metallic minerals in rock matrix, non-magnetic gray to blackish streak N.R.*
7. Iron Meteorite magnetic, black metallic metal, may have pitted surface, soluble in HCl	8. Carbonate easily scratched with knife, effervesces with HCl

*N.R.: no reaction with acid

Figure 33. Rock Sample Analysis Instructions (task provided by Dr. G. Rapp, University of Minnesota Geophysics Department)

MINERAL POINT COUNT TASK

To determine the percentages of three minerals in each of three size ranges by point counting with a binocular microscope. One unsorted sample contains all size ranges.

Materials: Quartz, a transparent white angular glossy mineral; Pyrite, a brass-yellow opaque mineral; Pyroxene, a greenish black glossy mineral.

Size ranges a: 42-60 mesh

b: 100-115 mesh

c: 150-200 mesh

Instrument: Binocular microscope

Problem: Determine the percentage of each mineral in each size range

	a	b	c
quartz			
pyrite			
pyroxene			
	100%	100%	100%

Figure 34. Mineral Point Count Task Instructions (task provided by Dr. G. Rapp, University of Minnesota Geophysics Department)

PETROGRAPHIC SLIDE ANALYSIS

Sampling judgment to determine how many distinctly different rock types are included in the given samples and therefore how many different samples should be collected to give adequate coverage. The samples are represented by mounted mineral grains. The single criterion for separation into rock types will be on the basis of mineral content.

Materials: 10 petrographic slide mounts of grains.

These 10 slides will contain an isotropic* mineral, an anisotropic** mineral, an anisotropic** mineral, and an opaque mineral in varying proportions.

Instrument: Petrographic microscope

Problem: Determine how many different rock samples you would collect from the samples (slides) given. The number is obviously between 1 and 10 with no "absolute" answer.

Slide No.	Collect Sample	Do Not Collect: Similar to Slide No.:
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

* An isotropic mineral transmits light with equal velocity in all directions thereby remaining dark and colorless under crossed nicols in a petrographic microscope.

** An anisotropic mineral breaks light into more than one wave and transmits each with a different velocity resulting in interference colors under crossed nicols in a petrographic microscope.

Figure 35. Petrographic Slide Analysis Instructions (task provided by Dr. G. Rapp, University of Minnesota Geophysics Department)

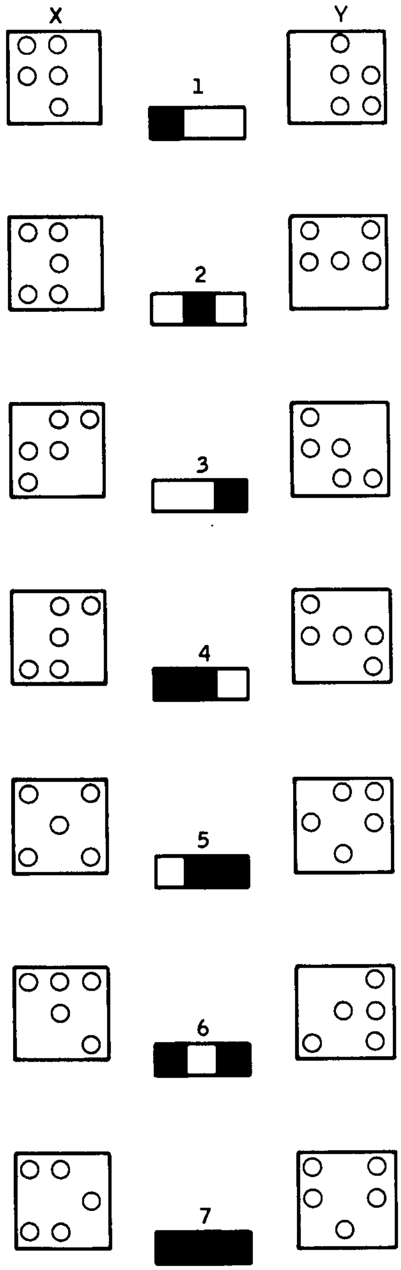


Figure 36. The Seven Pairs of Light Patterns and the Correct Response for Each

Pattern	Operator 1	Operator 2
1X	13	5
1Y	10	5
2X	3	3
2Y	5	4
3X	3	15
3Y	2	13
4X	12	6
4Y	12	7
5X	3	12
5Y	5	8
6X	2	2
6Y	1	1
7X	13	13
7Y	13	14

Figure 37. Total Number of Presentations of Each Pattern to Each Operator

Type of Run: 14- to 21-day simulation

Subject ____________
Time ____________
Date ____________

Duty Station: I, II, III, IV, V

Suit Condition: Shirt Sleeve
Ventilated Suit
Pressurized Suit

Task Tested ____________

	ADJECTIVE RATING	NUMERICAL RATING	DESCRIPTION
NORMAL OPERATION	Satisfactory	8	Excellent, includes optimum
		7	Good, pleasant to operate
		6	Satisfactory, but with some mildly unpleasant characteristics
EMERGENCY OPERATION	Unsatisfactory	5	Acceptable, but with unpleasant characteristics
		4	Unacceptable for normal operation
		3	Acceptable for emergency condition only
NO OPERATION	Unacceptable	2	Unacceptable even for emergency condition
		1	Unacceptable - intolerable
		0	Unacceptable - dangerous

Comments, if any:

Figure 38. Modified Cooper Evaluation Form

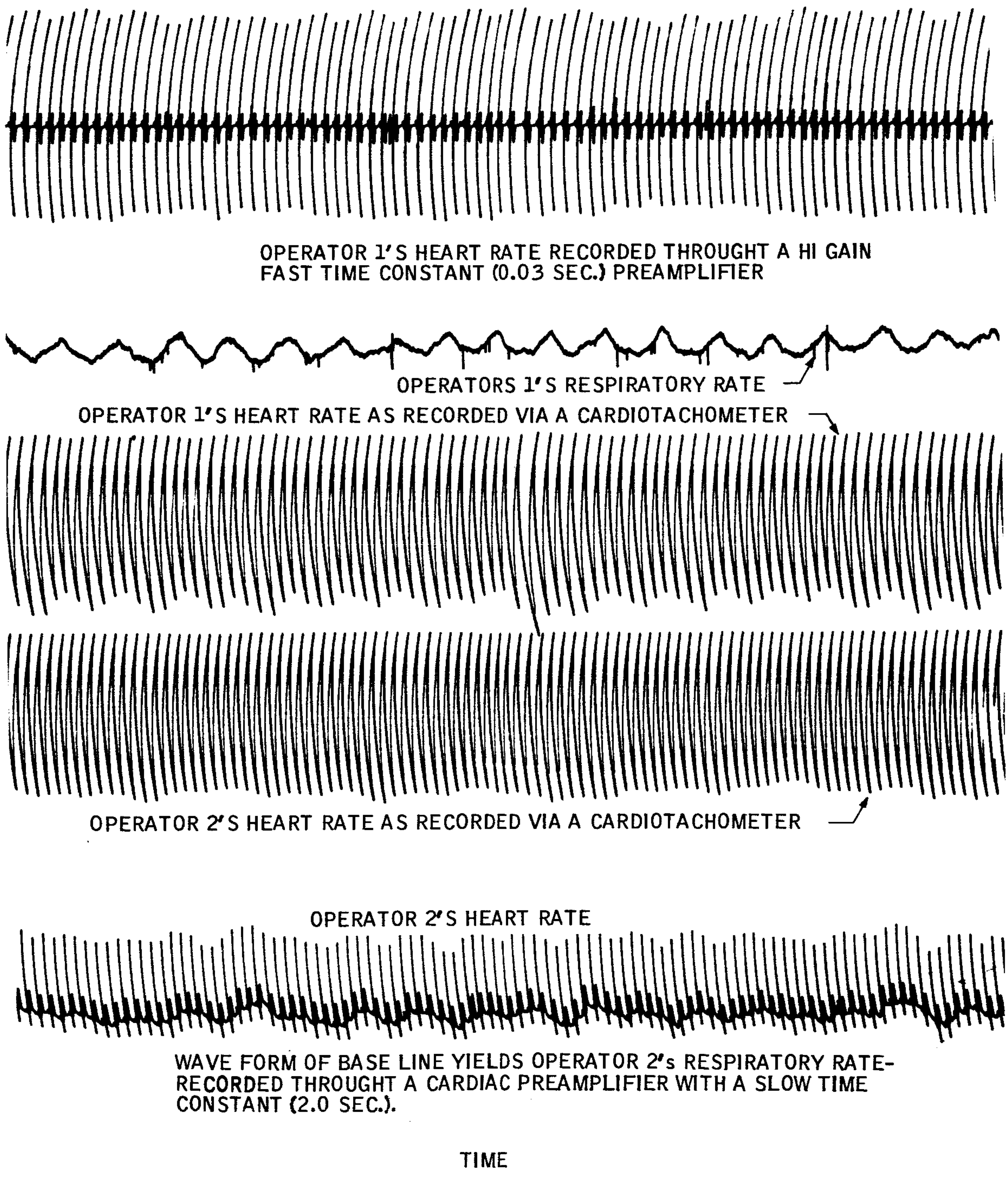


Figure 39. Sample Traces of Heart and Respiratory Rates Recorded During the Experiment

SEQUENCE A	SEQUENCE B
Take down beds	Take down beds
Electrode checkout	Electrode checkout
Personal hygiene	Personal hygiene
Eat	Eat
Suit checkout	Scientific tasks Audio balancing Sample measurement
Chart	Navigate
Drive	Monitor
Suit Don	Suit Don
Outside	Inside
Suit Doff	Suit Doff
Eat and hygiene	Eat and hygiene
Scientific tasks* Geophysical task	Scientific tasks Sample measurement Audio balancing
Navigate	Chart
Monitor	Drive
Scientific tasks Audio balancing Sample measurement	Suit checkout
Suit Don	Suit Don
Inside	Outside
Suit Doff	Suit Doff
Eat and hygiene	Eat and hygiene
Scientific task Sample measurement Audio balancing	Scientific task Geophysical task
Navigate	Chart
Drive	Monitor
Scientific Tasks Audio balancing Sample measurement	Scientific Tasks Sample measurement Audio balancing
Eat	Eat
Remove electrodes	Remove electrodes
Hygiene	Hygiene
Set up beds	Set up beds
Retire	Retire

Figure 40. LUNEX II Task Sequence - 24 Hours

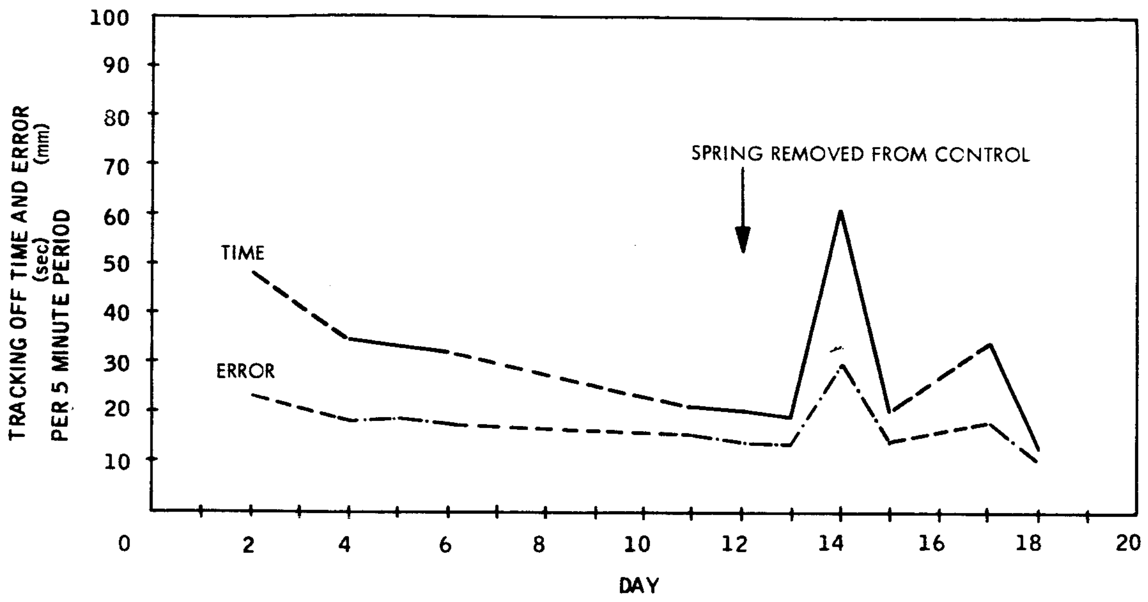


Figure 41. Tracking Off- Time and Error - Both Operators, Speeds 1 and 2

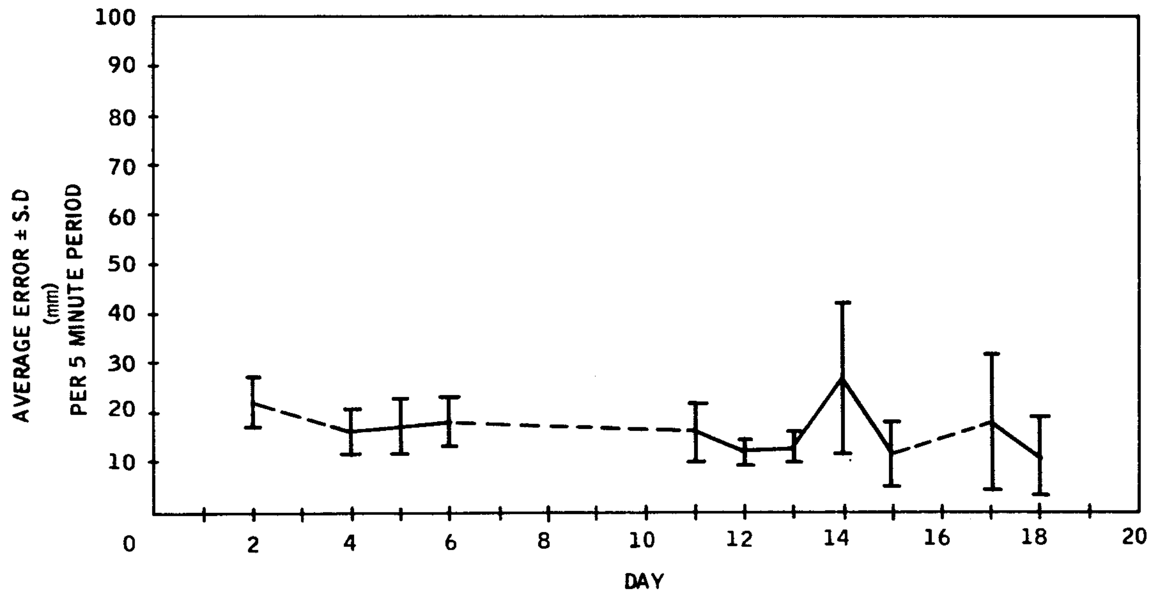


Figure 42. Tracking Error - Both Operators, Speed 1

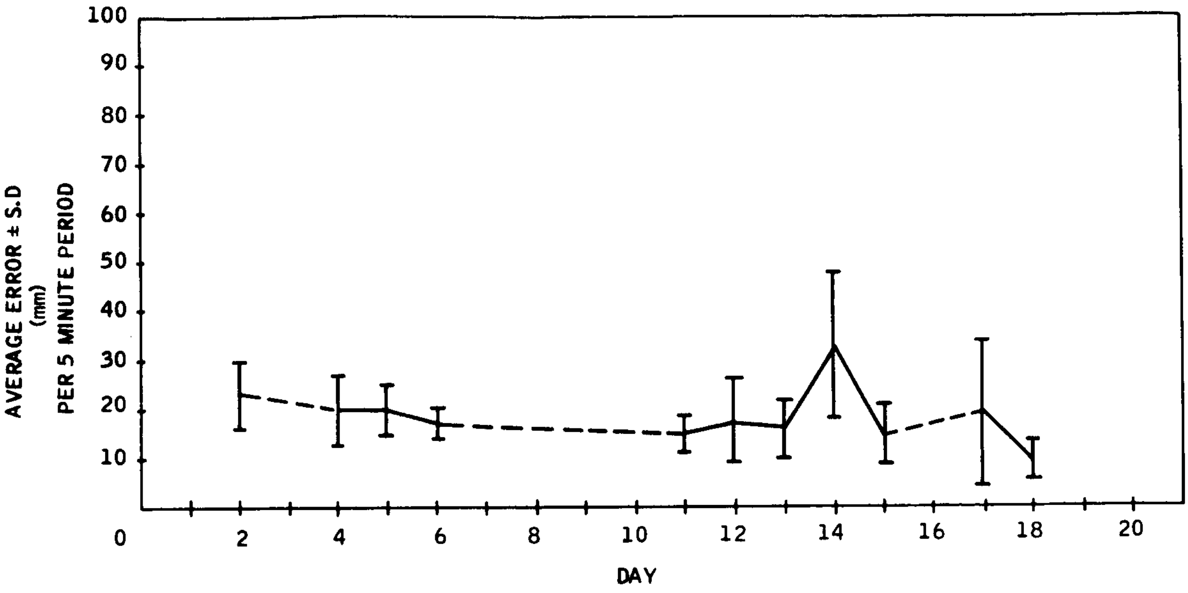


Figure 43. Tracking Error - Both Operators, Speed 2

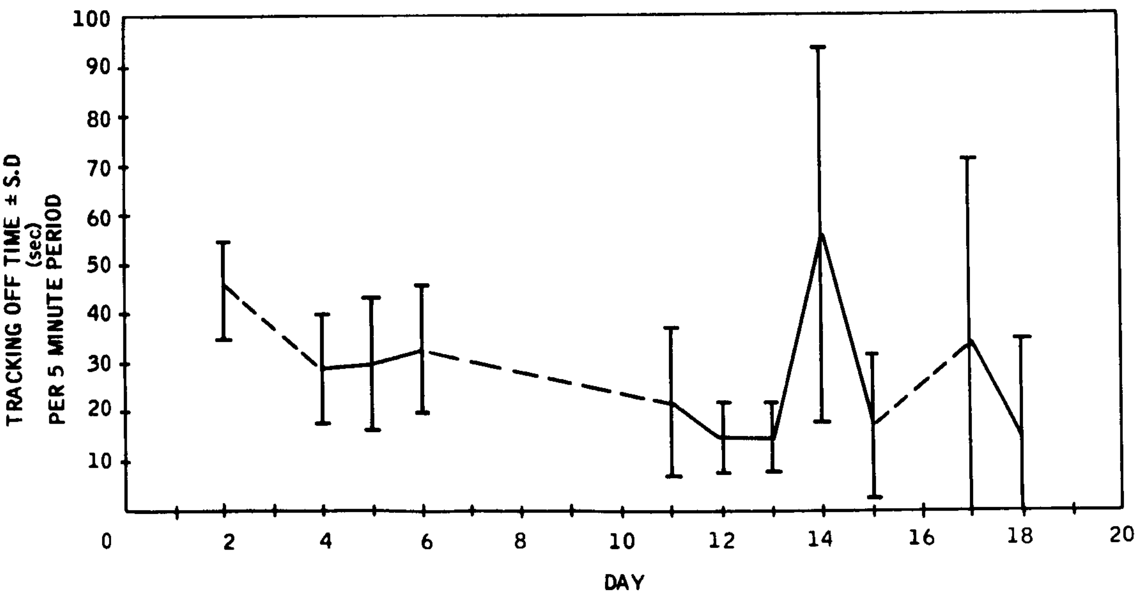


Figure 44. Tracking Off- Time - Both Operators, Speed 1

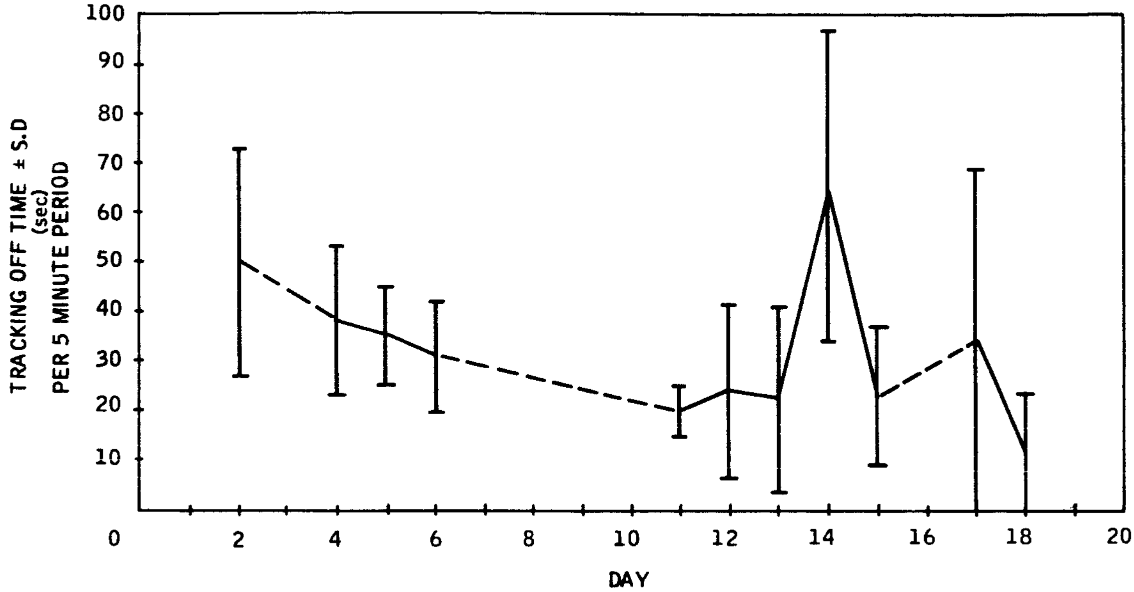


Figure 45. Tracking Off-Time - Both Operators, Speed 2

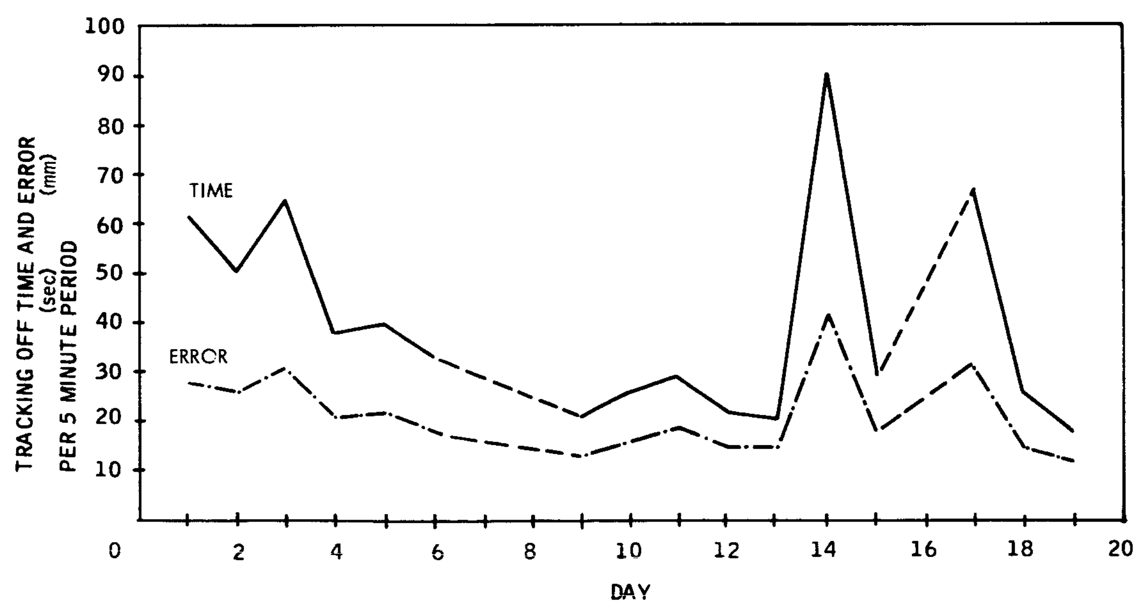


Figure 46. Tracking Off-Time and Error - Operator 1, Speeds 1 and 2

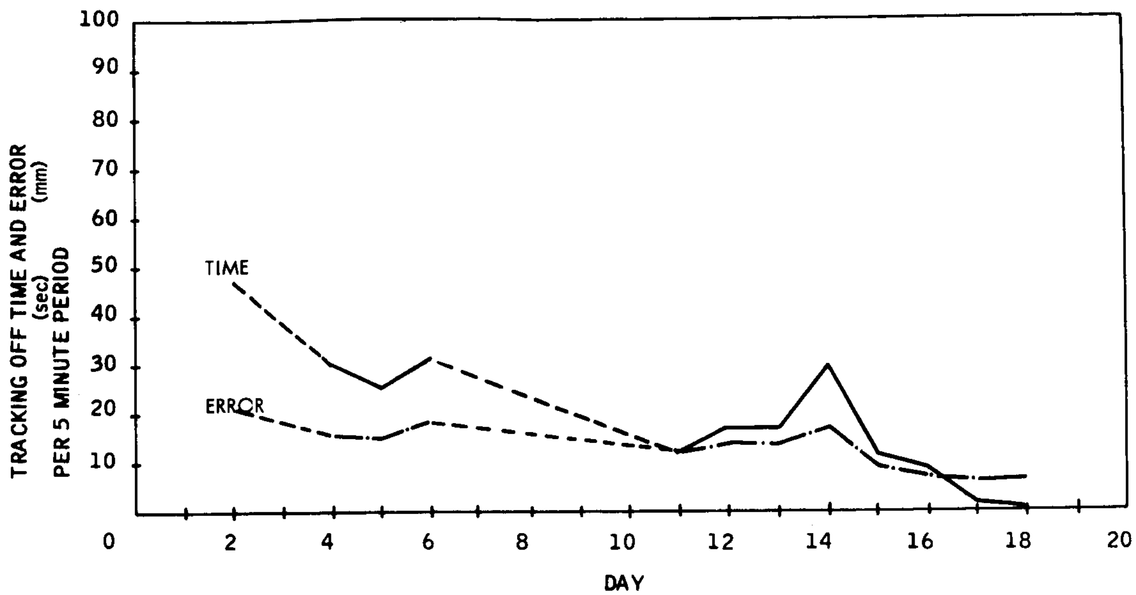


Figure 47. Tracking Off-Time and Error - Operator 2, Speeds 1 and 2

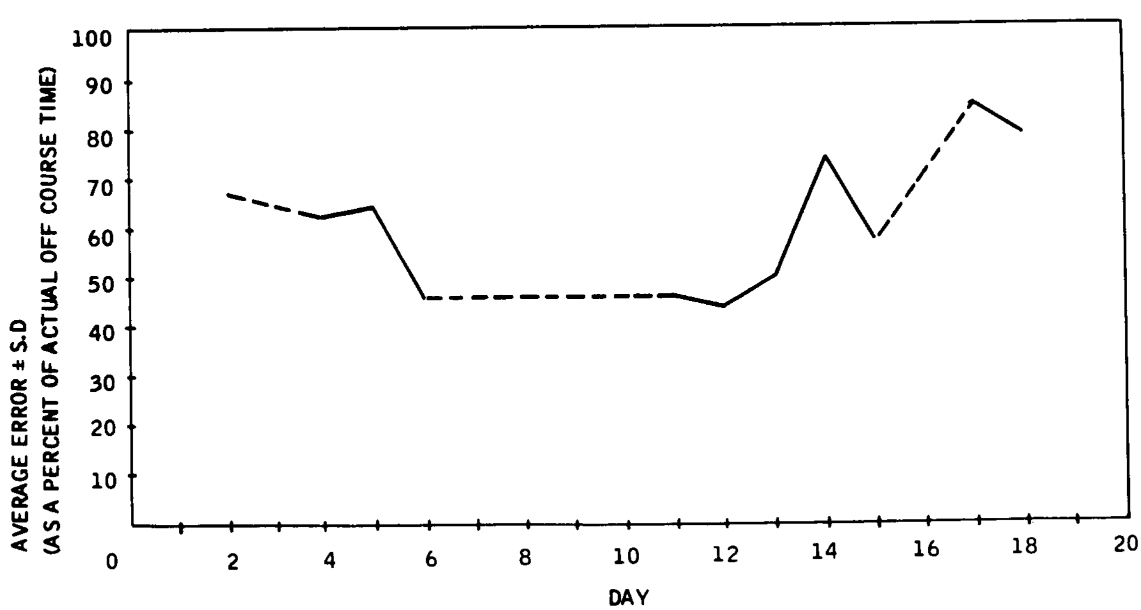
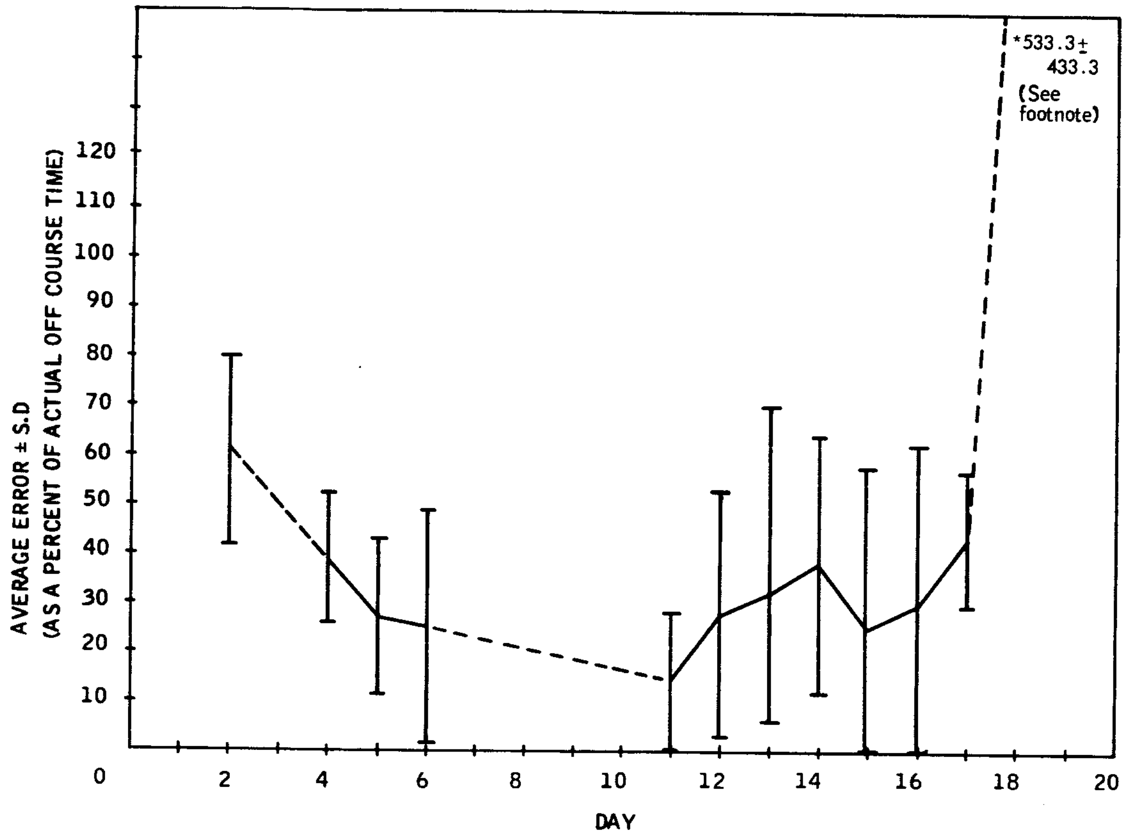


Figure 48. Average Percent Monitoring Error - Both Operators, Speeds 1 and 2



* OPERATOR 2'S DRIVING WAS EXCEPTIONALLY GOOD ON DAY 18 HENCE HIS OFF COURSE TIME WAS EXTREMELY SMALL, RESULTING IN A HIGH PERCENTAGE ERROR FOR OPERATOR 1'S MONITORING-SEE TEXT.

Figure 49. Average Percent Monitoring Error - Operator 1, Speed 1

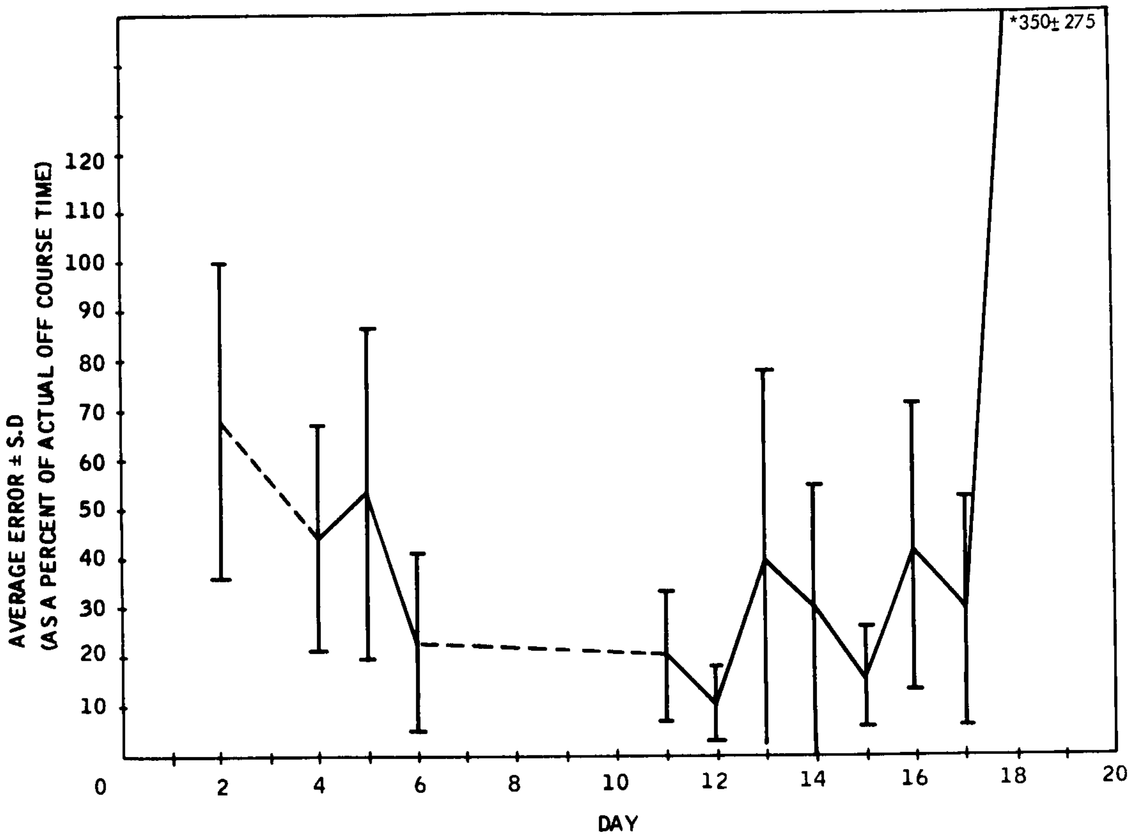


Figure 50. Average Percent Monitoring Error - Operator 1, Speed 2

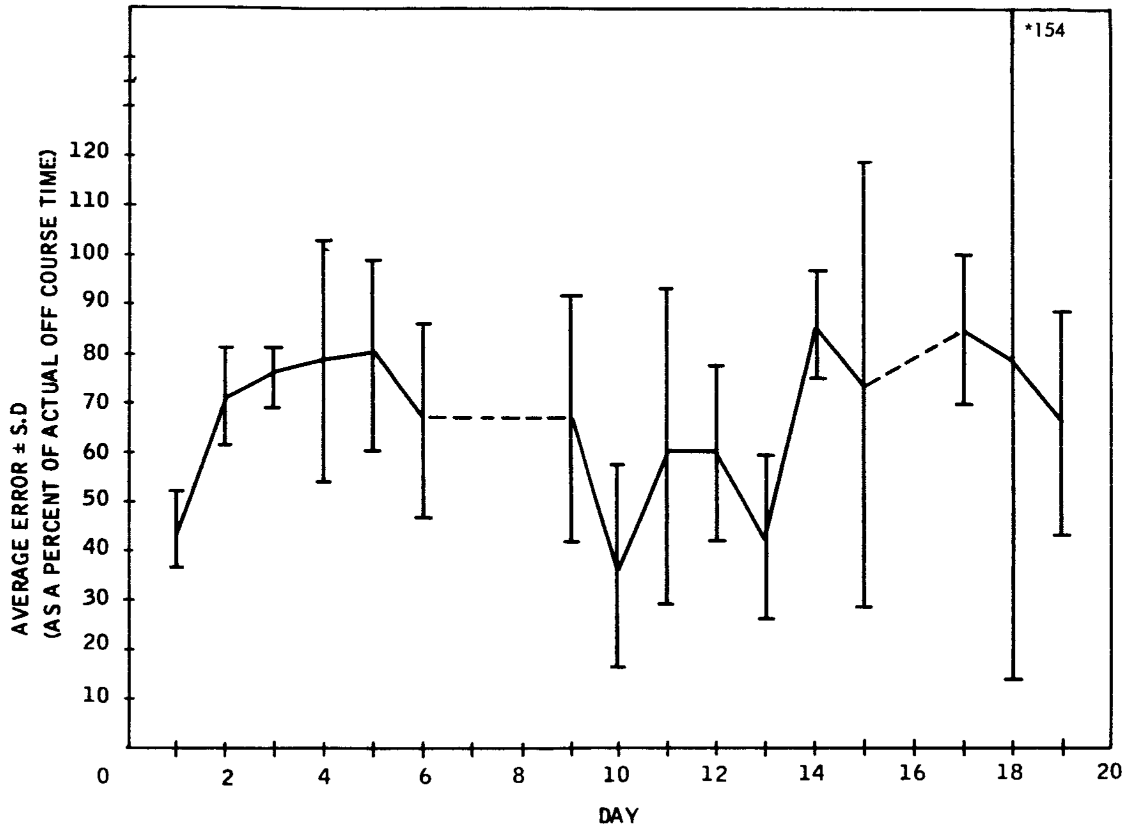


Figure 51. Average Percent Monitoring Error - Operator 2, Speed 1

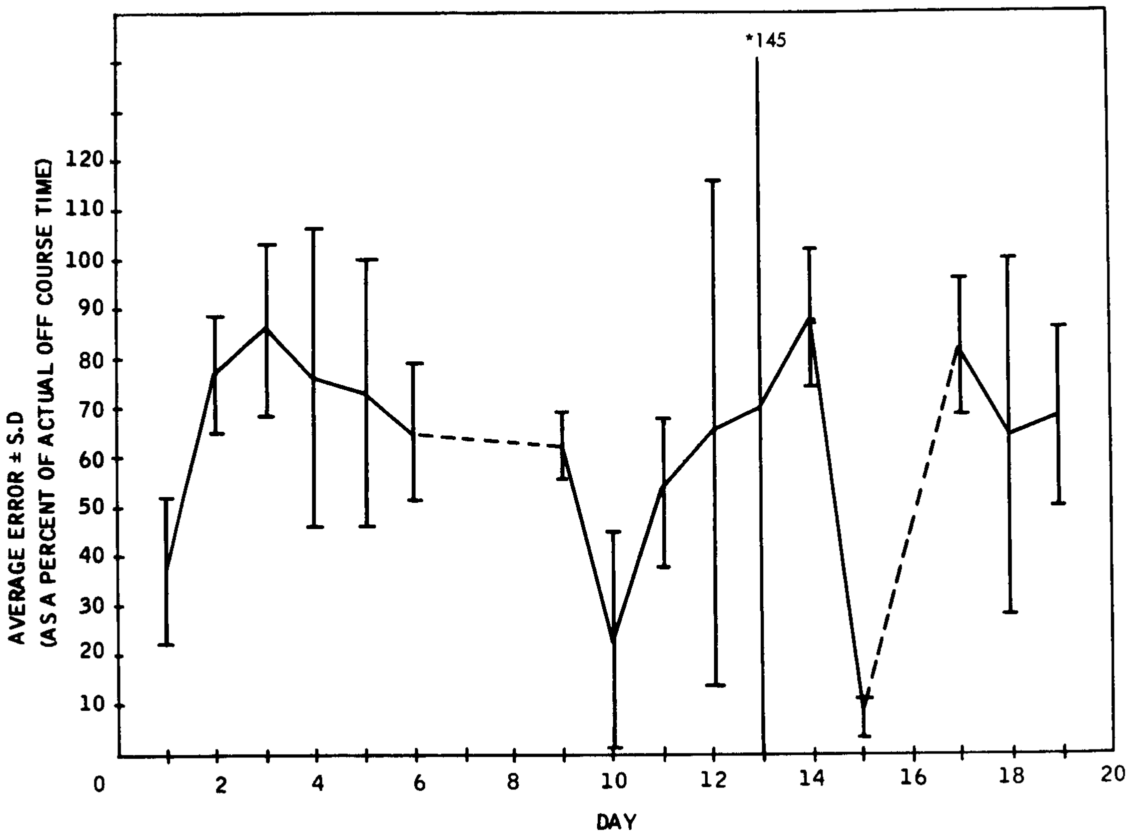


Figure 52. Average Percent Monitoring Error - Operator 2, Speed 2

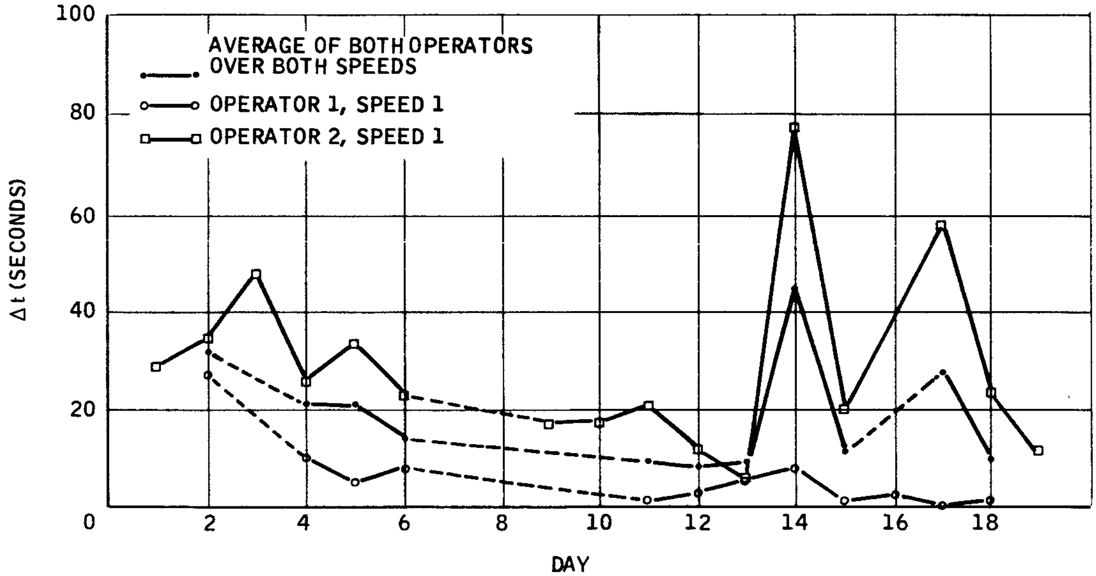
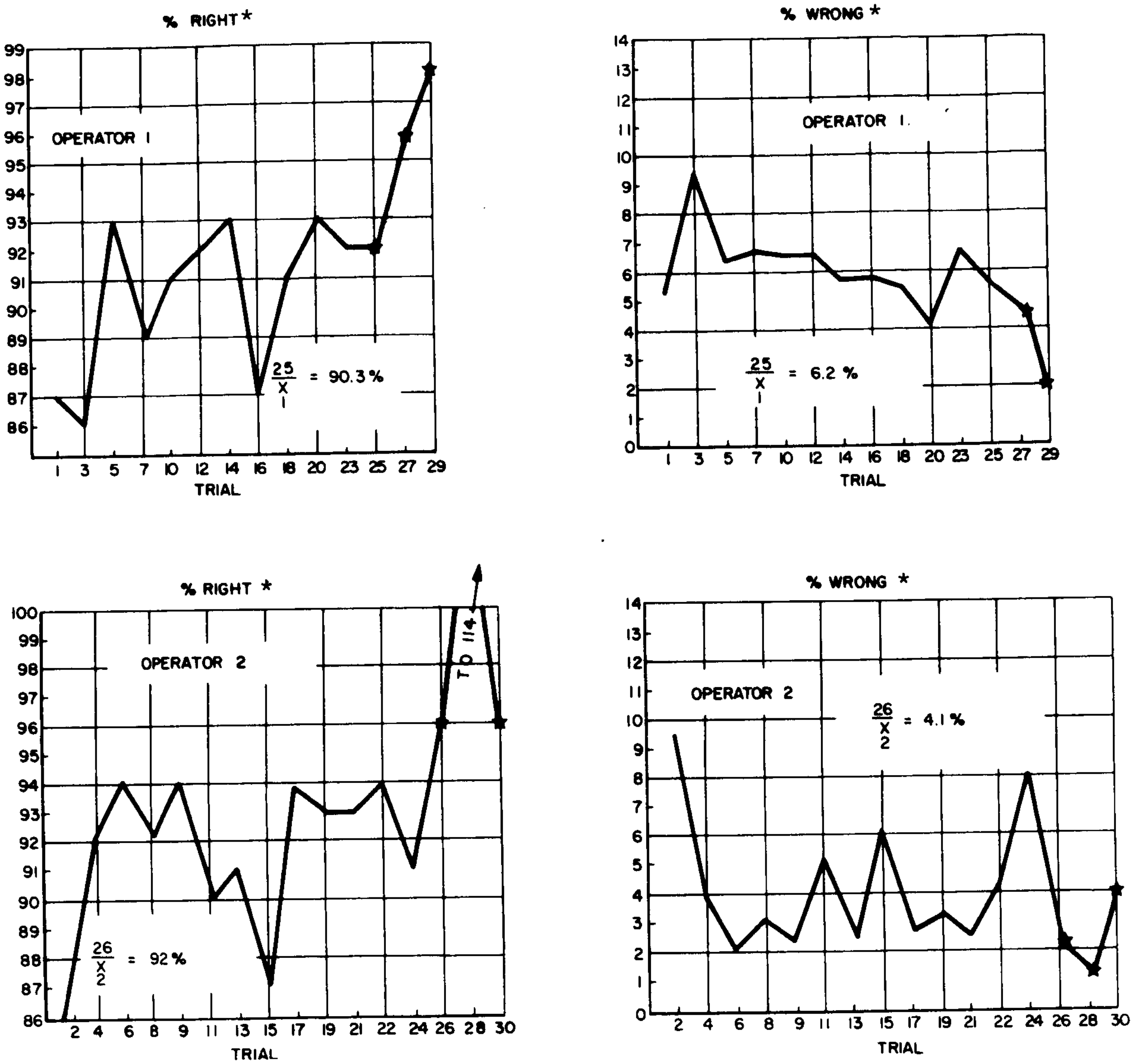


Figure 53. Average Monitoring Error (Δt) versus Days in the Simulator (Δt is the difference between the time monitor's switch was depressed and the time the driver was off-course averaged per 5-minute driving period)



* The percent right is independent of the percent wrong since during each 1.5-second presentation, the subject could make no response, one response either correct or incorrect, or several responses correct or incorrect.

Figure 54. Change-No-Change Pattern Monitoring Task Results

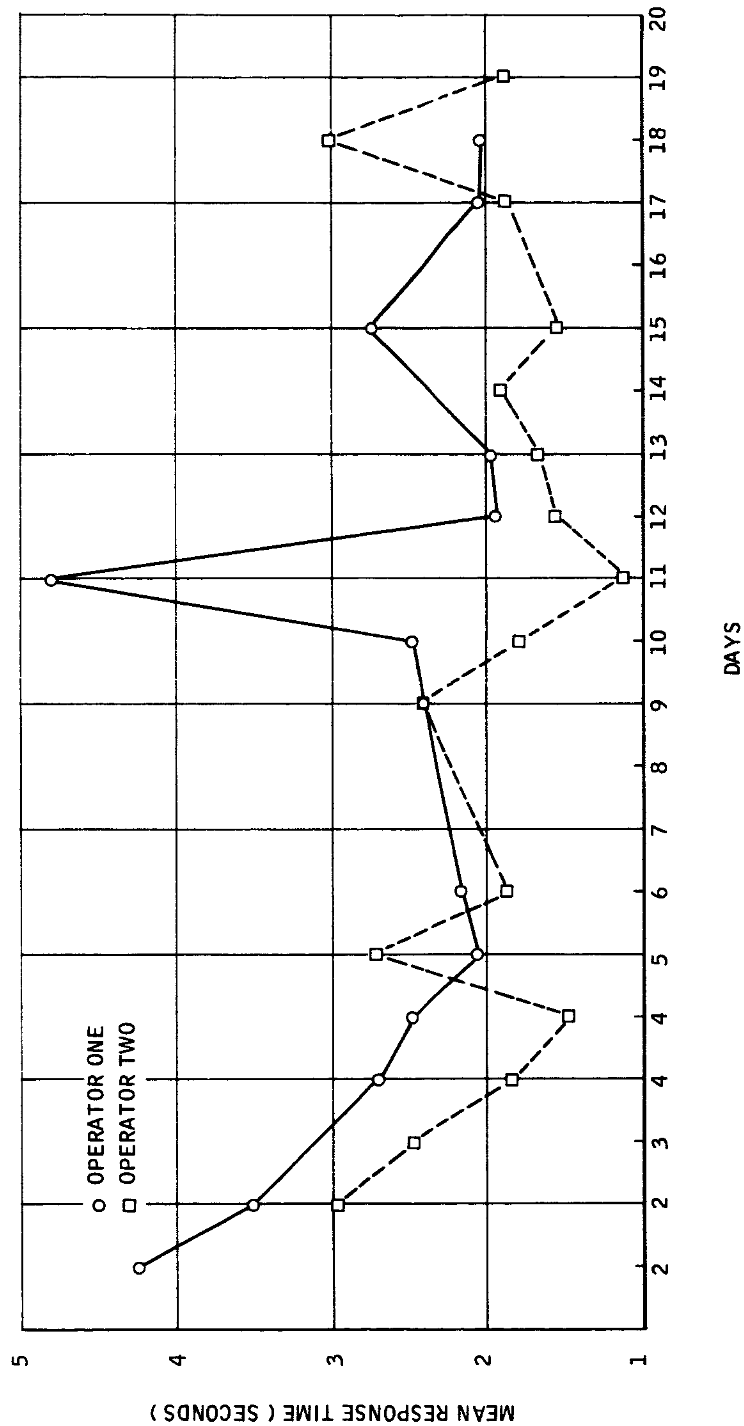


Figure 55. Mean Response Time to Correct Response - Per Day

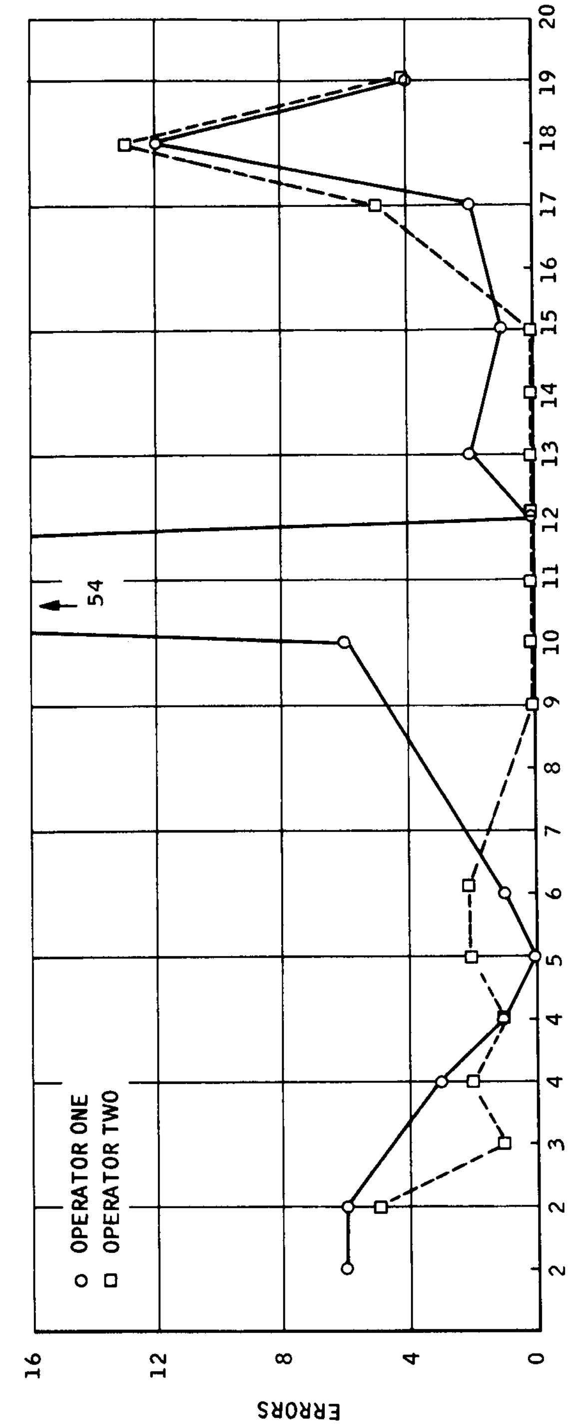


Figure 56. Total Error Per Day

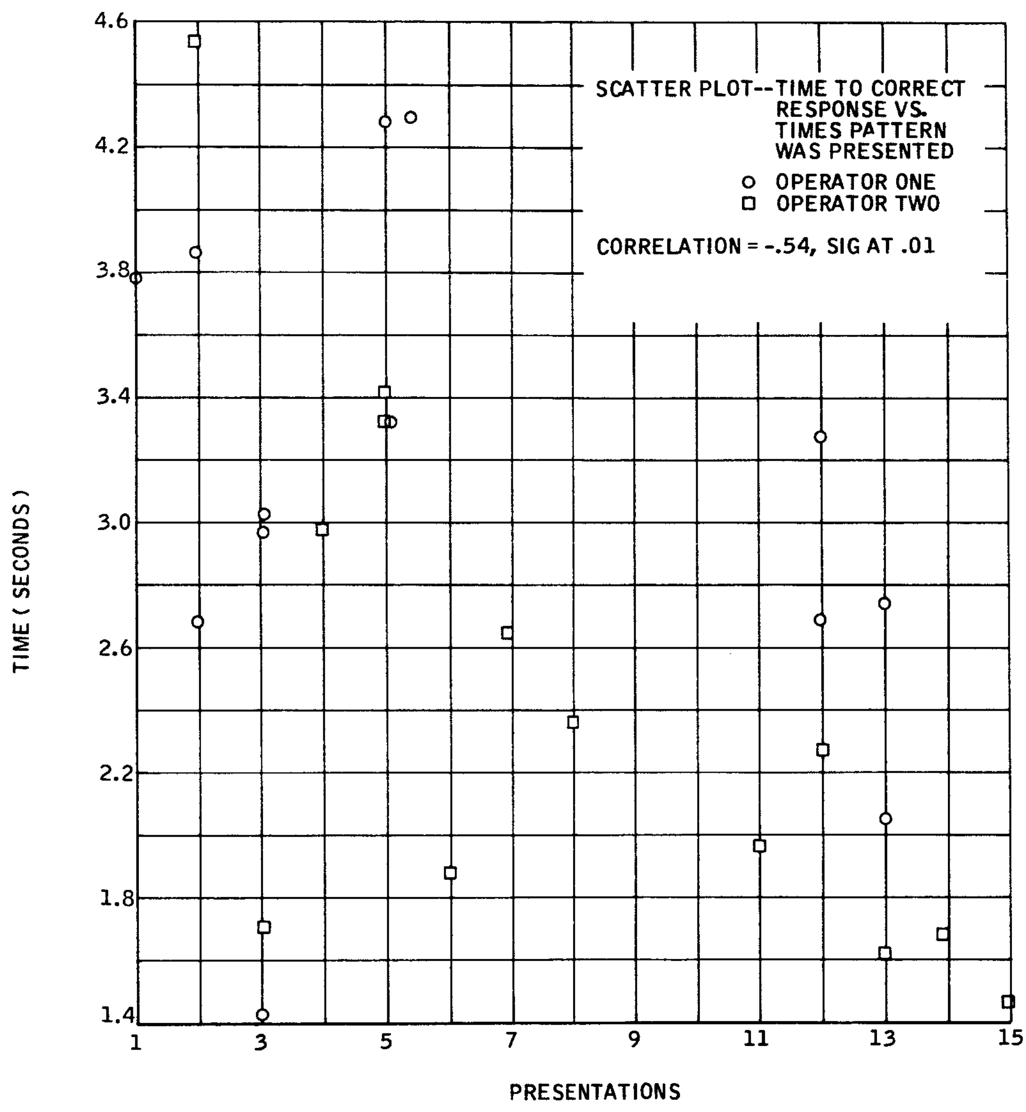


Figure 57. Scatterplot of Time to Correct Response versus Times Pattern was Presented

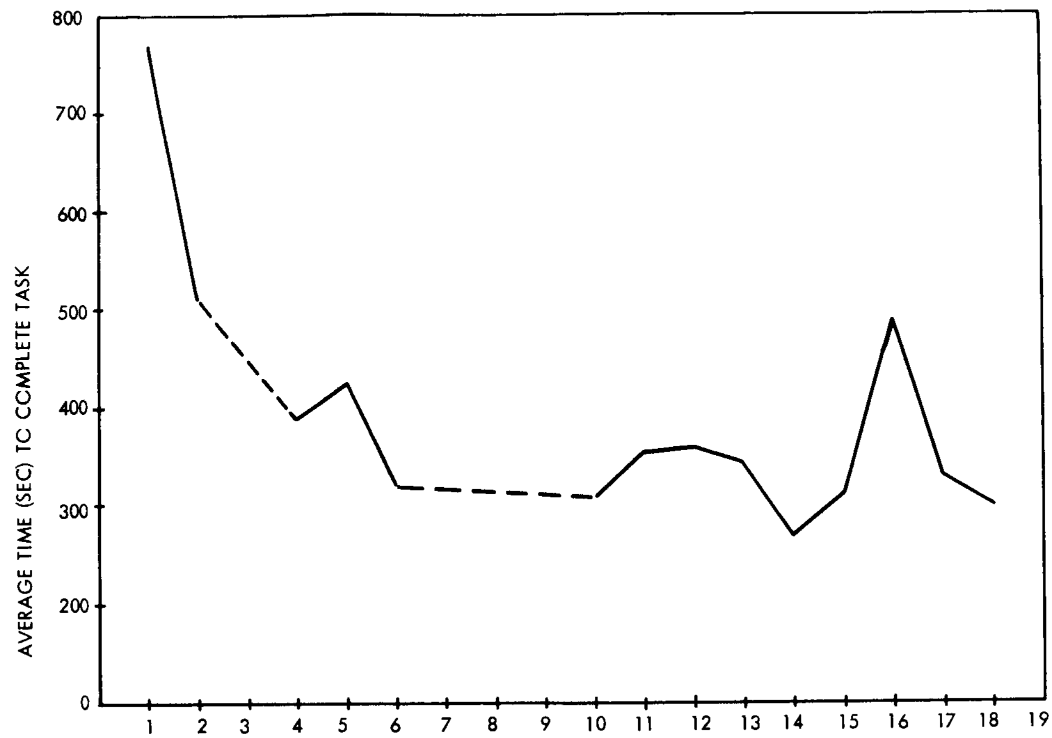


Figure 58. Average Time to Complete Navigation Task - Both Operators

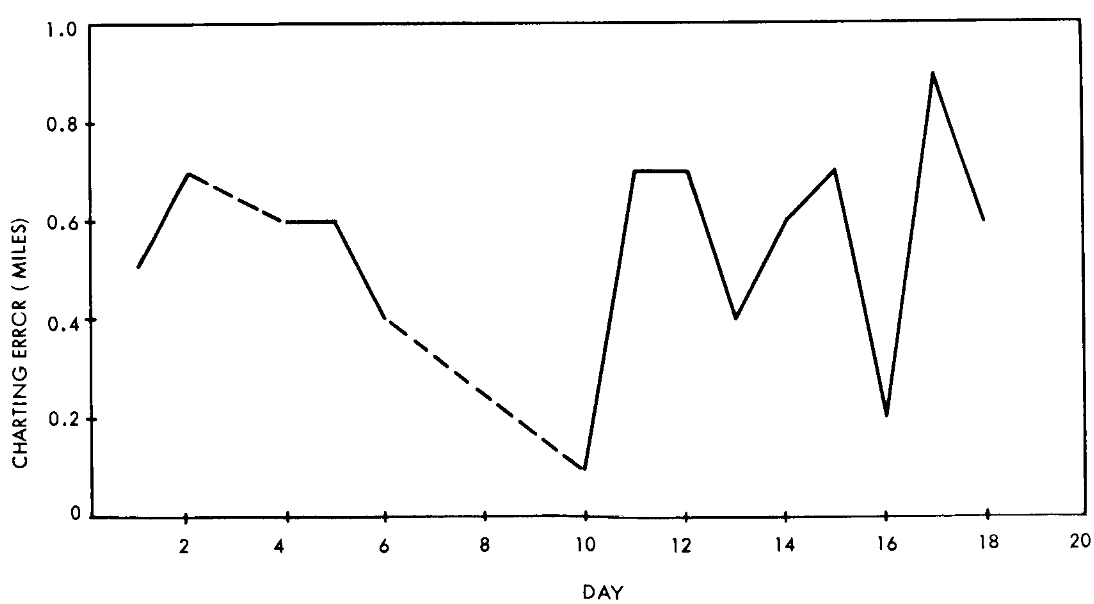


Figure 59. Average Navigation Charting Error - Both Operators

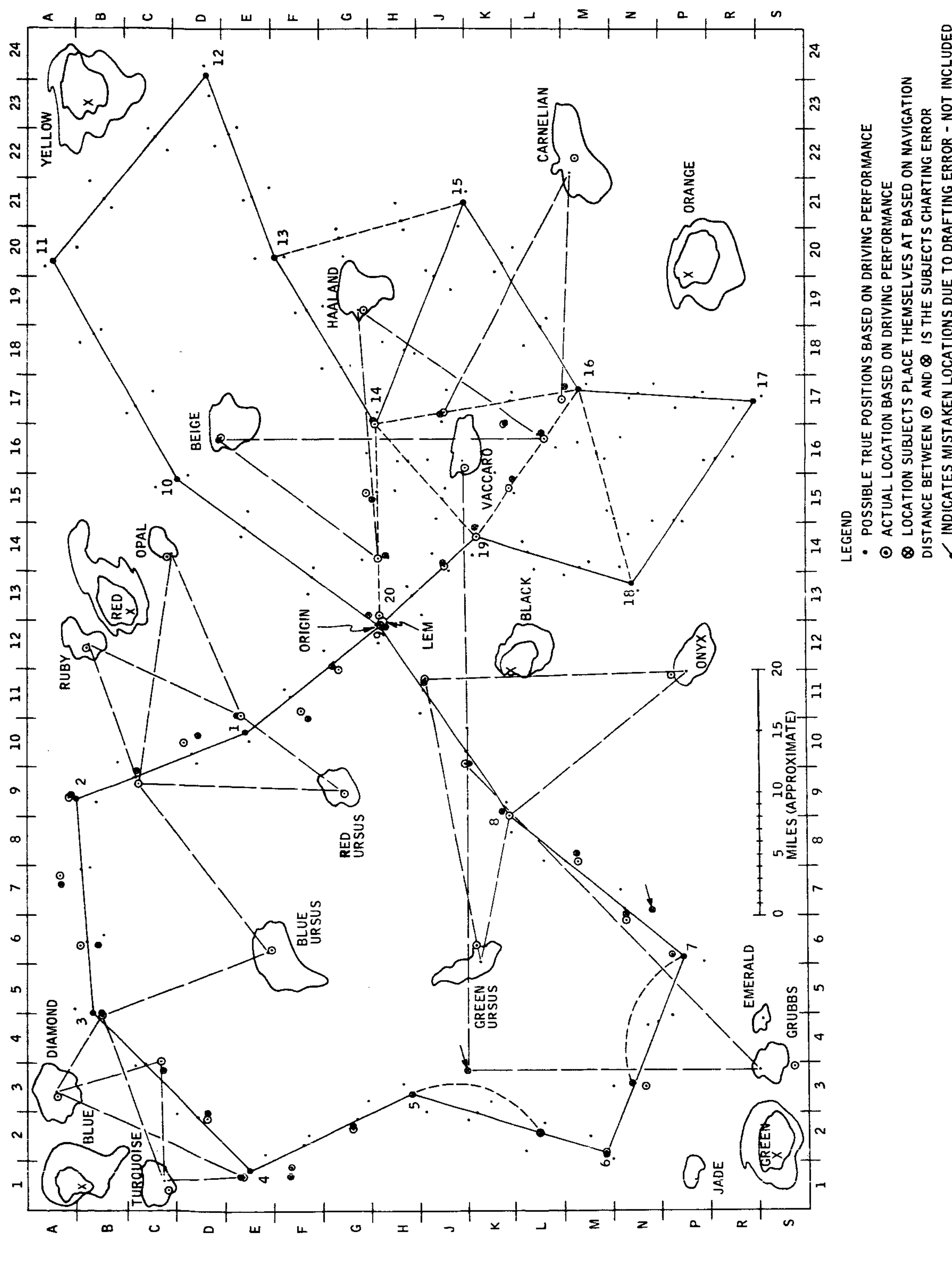


Figure 60. Experimenters' Map of Lunar Surface Traverse

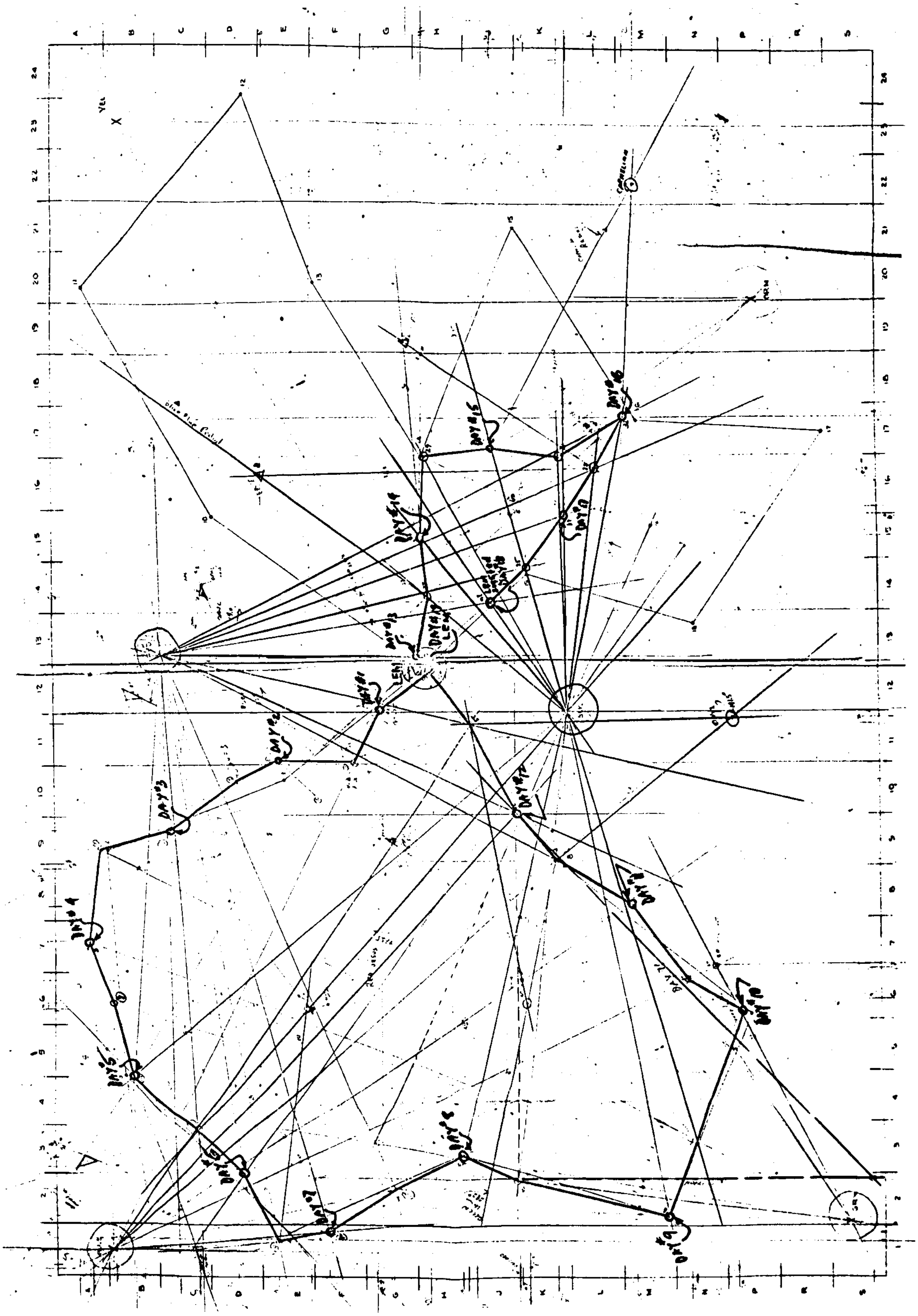


Figure 61. Map of Lunar Surface Traverse Drawn by Subjects

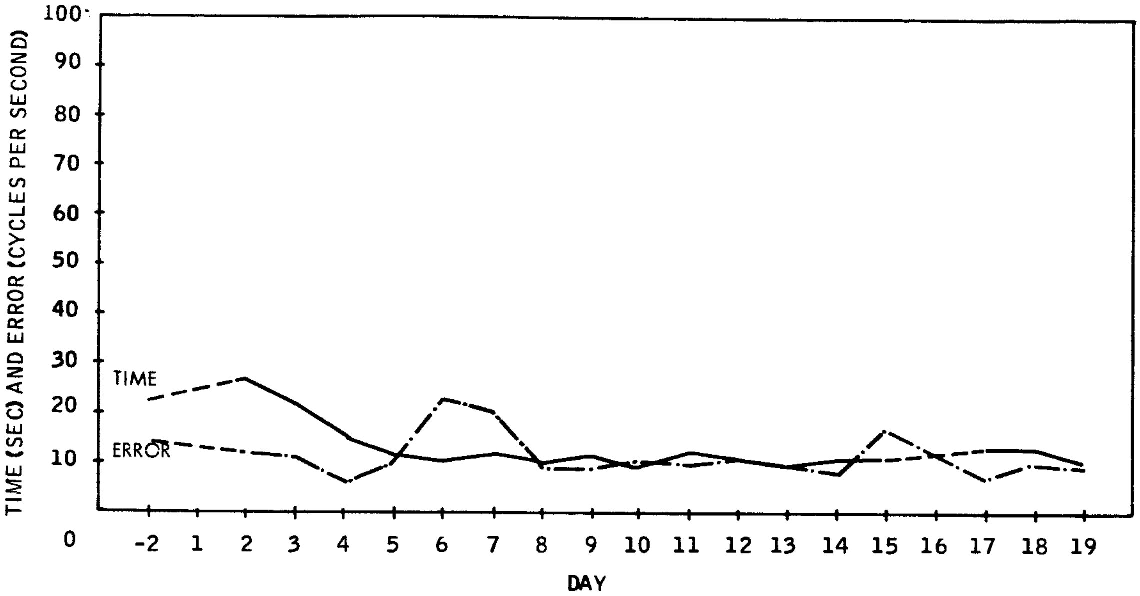


Figure 62. Audio-Balancing Task Average Time and Error - Both Operators

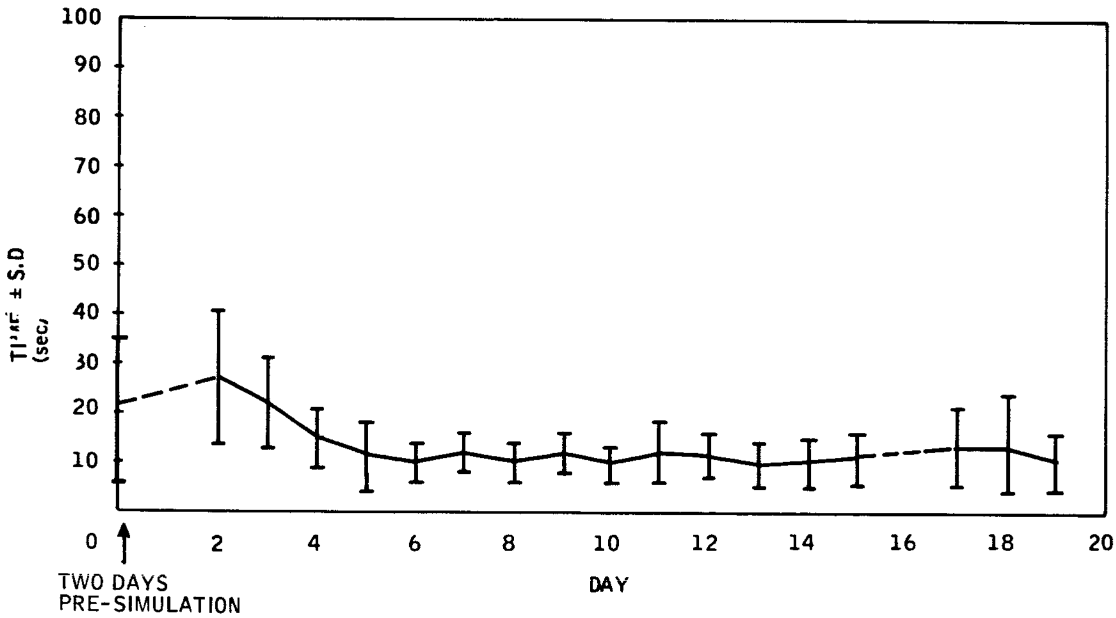


Figure 63. Audio-Balancing Task Average Time and Standard Deviations - Both Operators

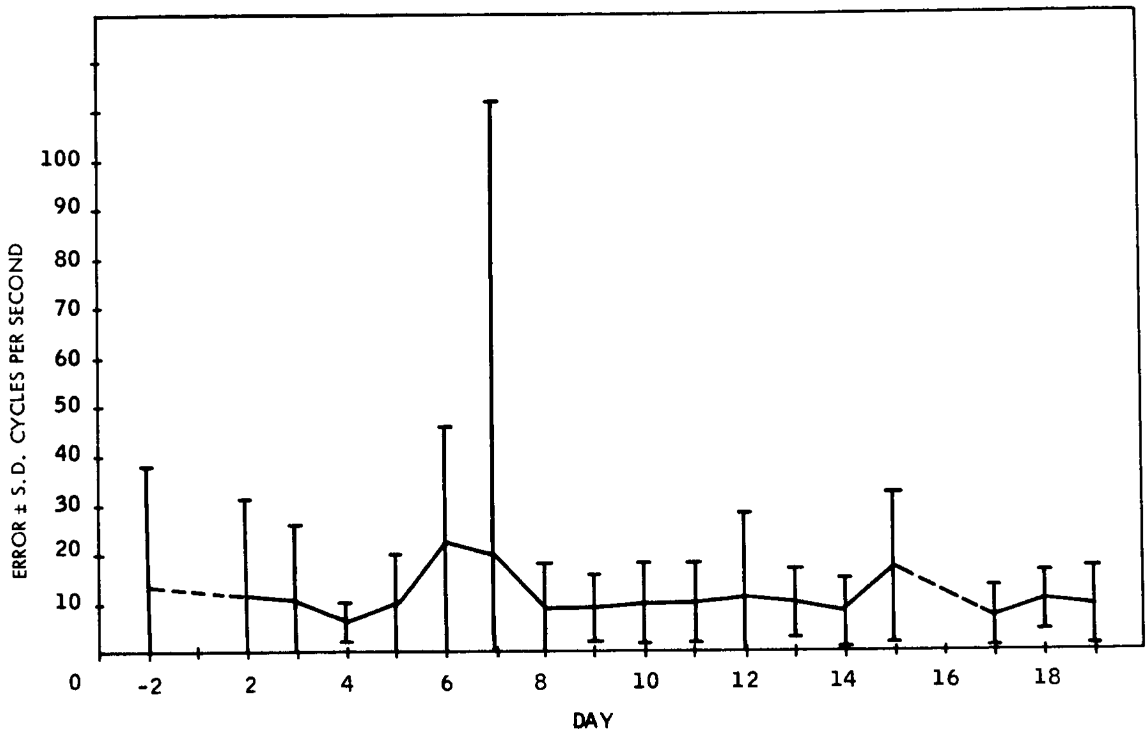


Figure 64. Audio-Balancing Task Average Error and Standard Deviations - Both Operators

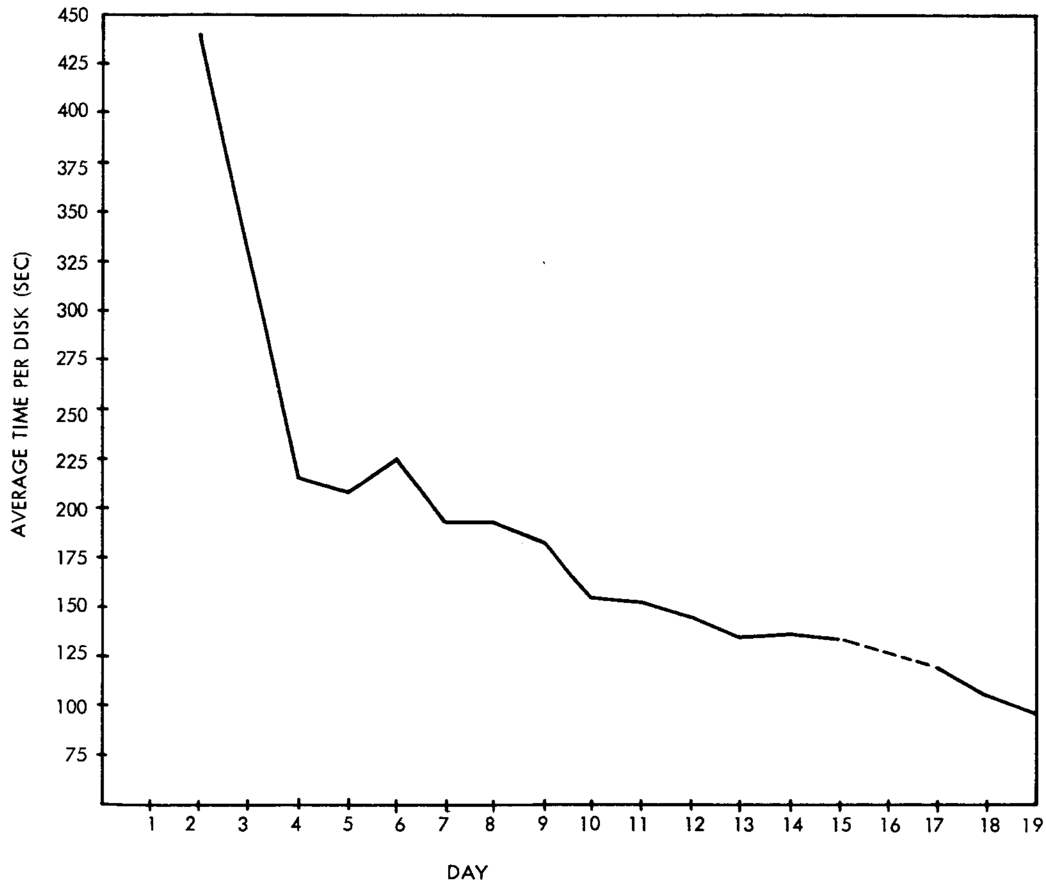


Figure 65. Sample Measurement - Average Time to Measure One Disc, Both Subjects

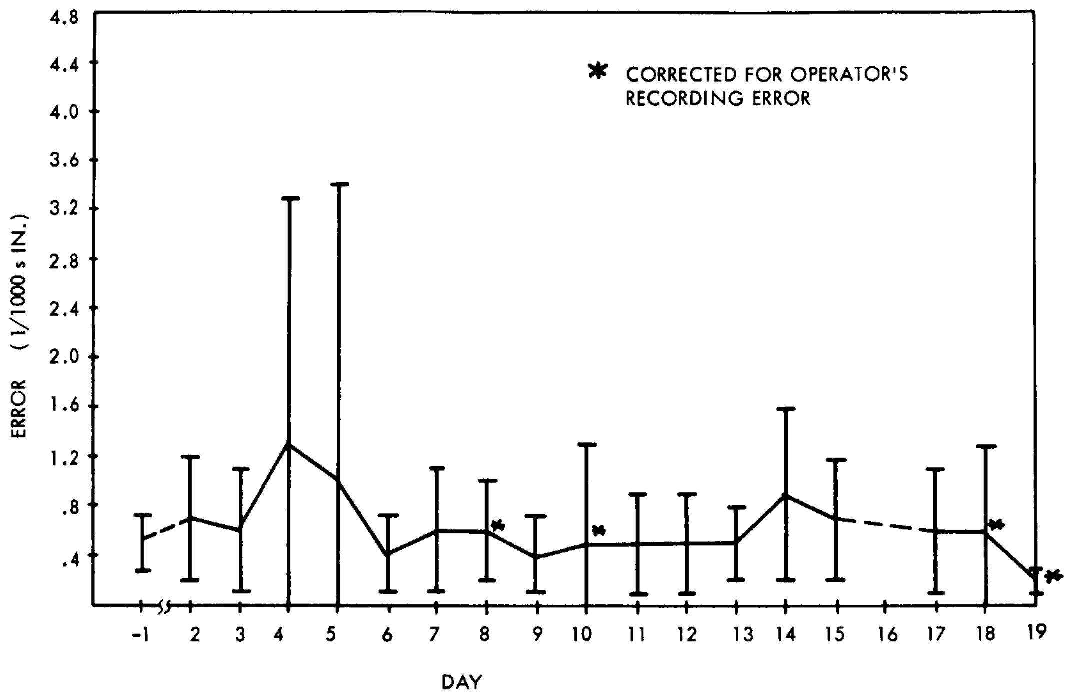


Figure 66. Sample Measurement - Average Error Per Disc ±S. D., Both Subjects

Problem introduction: This problem requires a sampling judgement to determine how many distinctly different rock types are included in the given samples and therefore how many different samples should be collected to give adequate coverage. The samples are represented by mounted mineral grains. The single criterion for separation into rock types will be on the basis of mineral content.

Materials: 10 petrographic slide mounts of grains.

These 10 slides will contain an isotropic*, I, mineral, an anisotropic**A, mineral, and an opague, O, mineral in varying proportions.

Instrument: Petrographic microscope. (Polarizing)

Problems: Determine how many different rock samples you would collect from the samples (slides) given. The number is obviously between 1 and 10 with no "absolute" answer.

These "answers" are based on the initial weighing out of components

Slide No.	Collect Sample	Do Not Collect: Similar to Slide No.___	
1	X		(1/2 I, 1/2 A)
2	X		(1/3 I, 1/3 A, 1/3 O)
3	X		(all A)
4	X		(9/10 A, 1/10 opague)
5		X	(1/3 I, 1/3 A, 1/3 O)
6	X		(1/2 I, 1/2 O)
7		X	(9/10 A, 1/10 opague)
8		X	(1/2 I, 1/2 A)
9		X	(1/2 I, 1/2 A)
10		X	(all A)

* An isotropic mineral I transmits light with equal velocity in all directions thereby remaining dark and colorless under crossed nicols in a petrographic microscope.

** An anisotropic A mineral breaks light into more than one wave and transmits each with a different velocity resulting in interference colors under crossed nicols in a petrographic microscope.

Figure 67. Score Sheet for Petrographic Slide Analysis

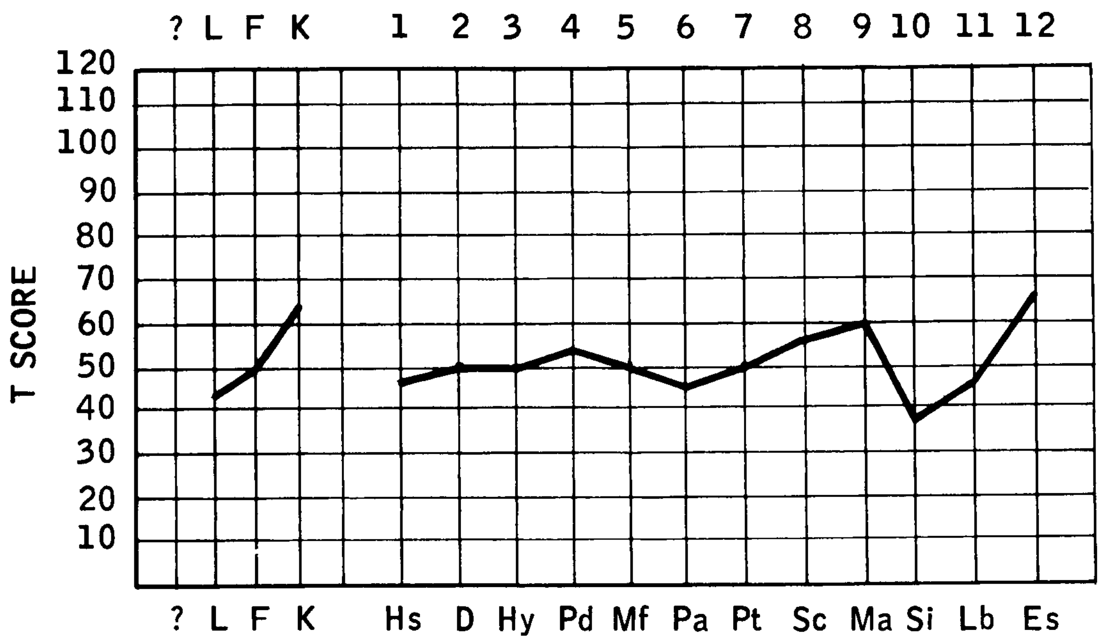


Figure 68. Normalized MMPI Profile - Operator 1, Pre-Simulation

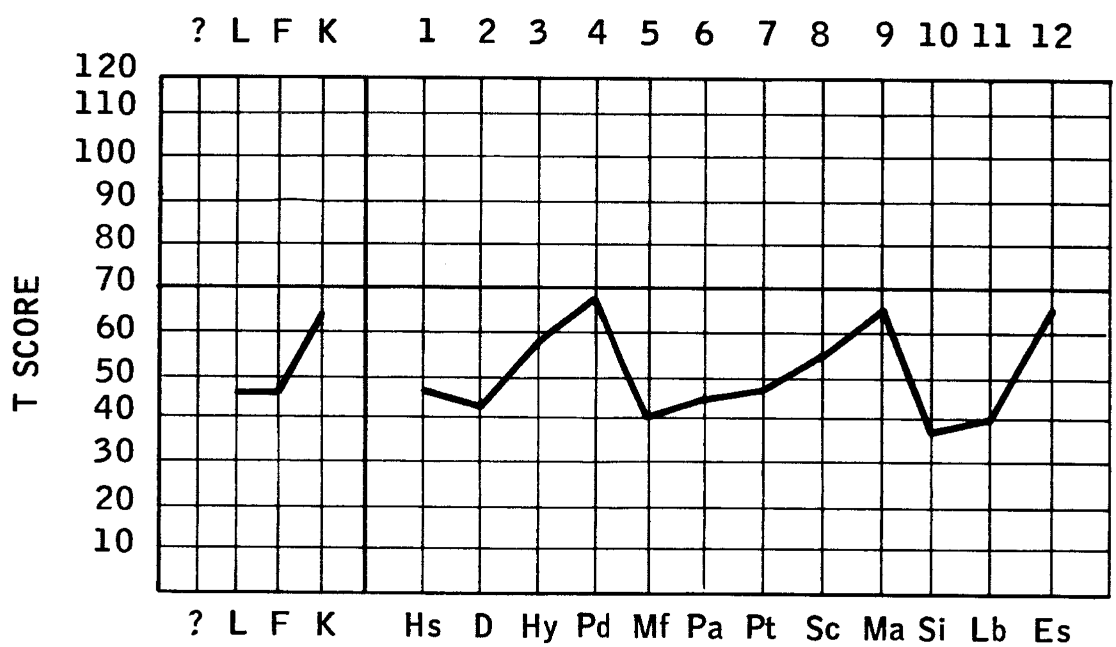


Figure 69. Normalized MMPI Profile - Operator 1, Post-Simulation

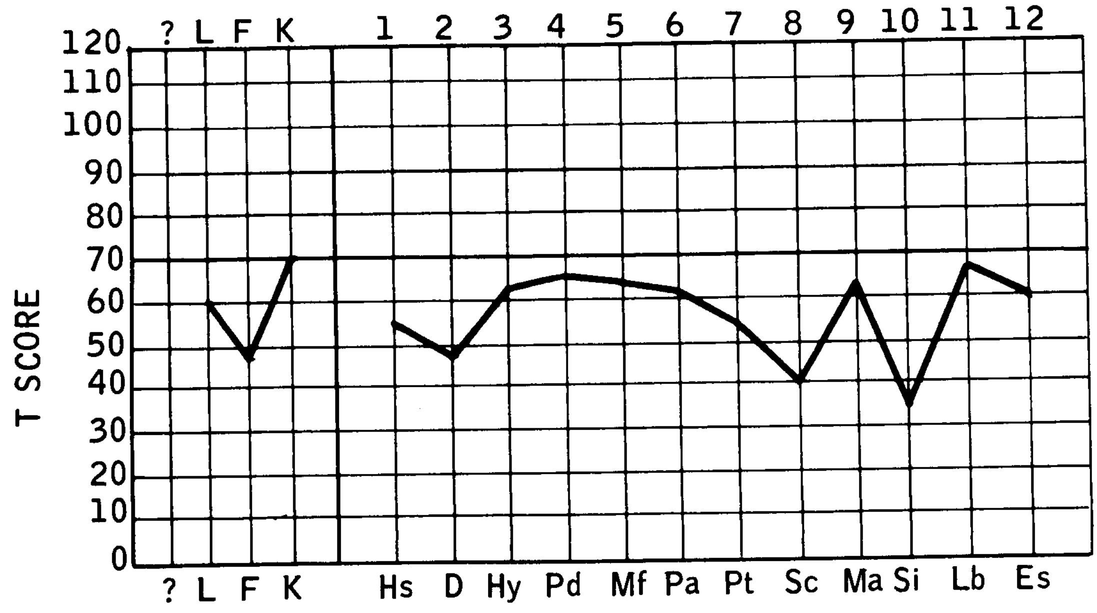


Figure 70. Normalized MMPI Profile - Operator 2, Pre-Simulation

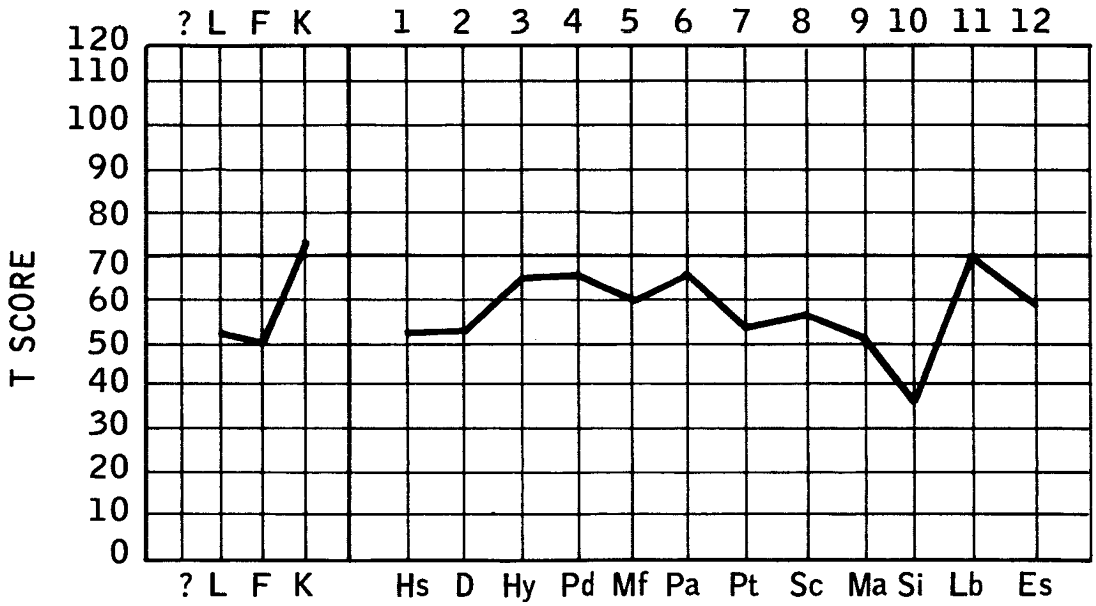


Figure 71. Normalized MMPI Profile - Operator 2, Post-Simulation

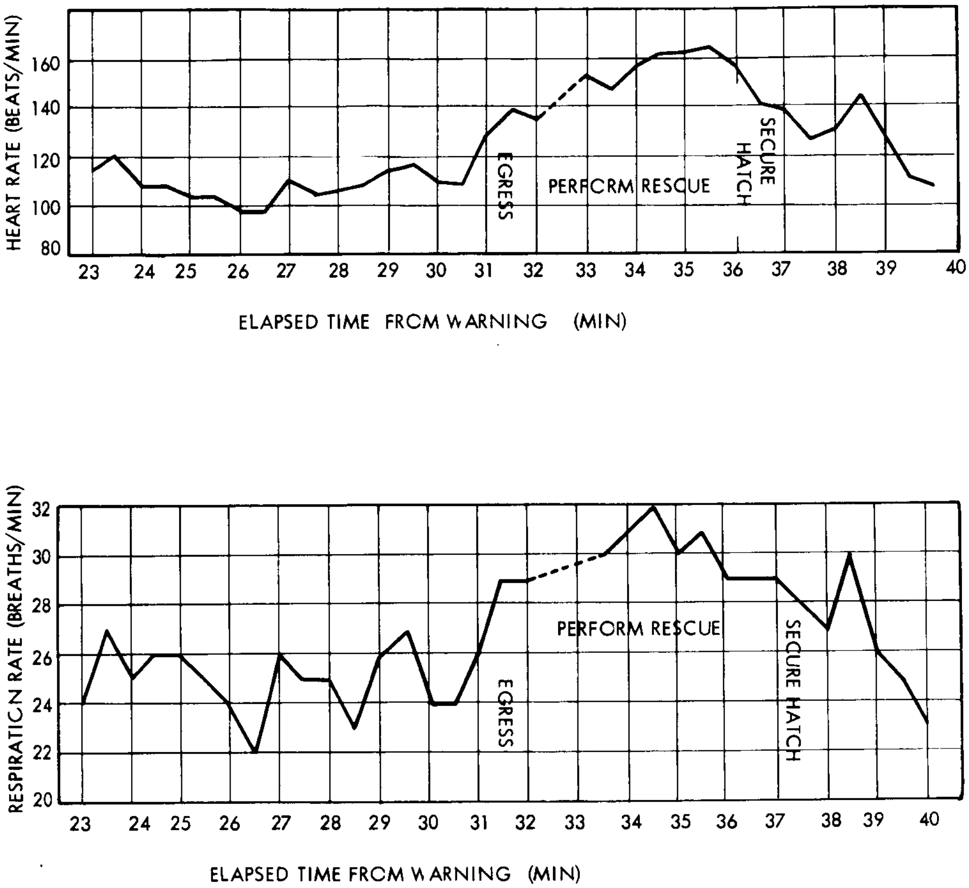


Figure 72. Operator 2 Heart and Respiratory Rates - Emergency Rescue

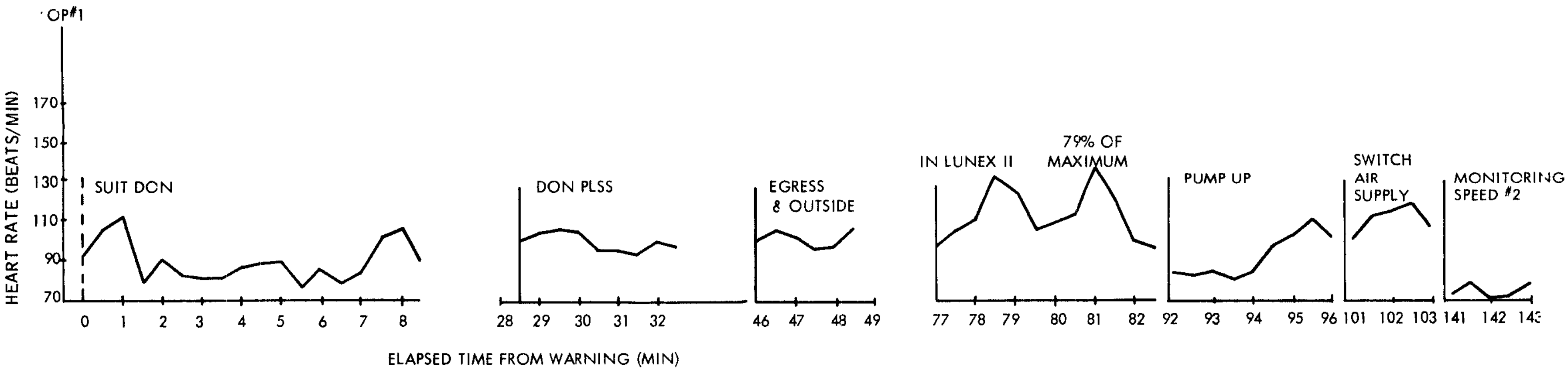


Figure 73. Operator 1 Heart Rates - Simulated Cabin Pressure Failure

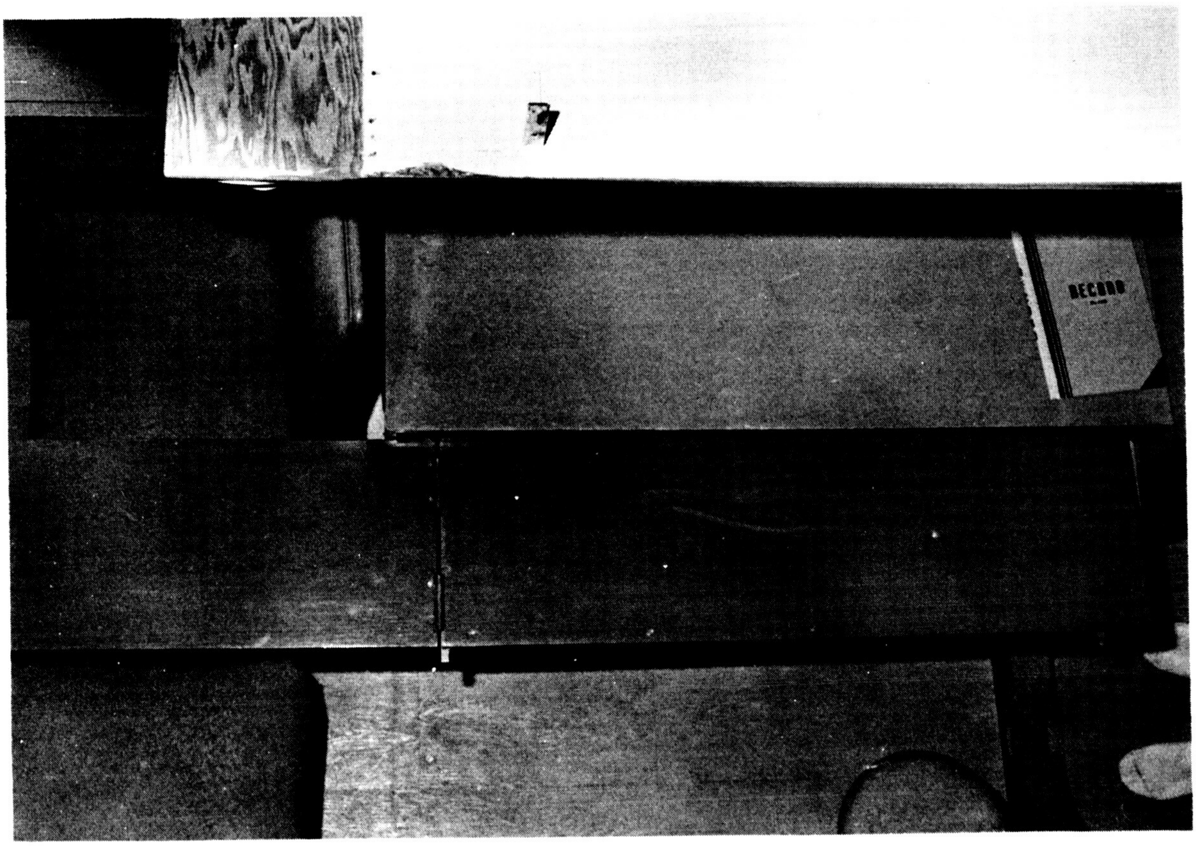


Figure 74. Partial Extension of the Upper Bunk, Permitting Aisle Access with Greatly Increased Workspace Area

Figure 75. Use of Upper Bunk During Temporary Disablement of One Crew Member (subject on upper bunk has access to all tasks)

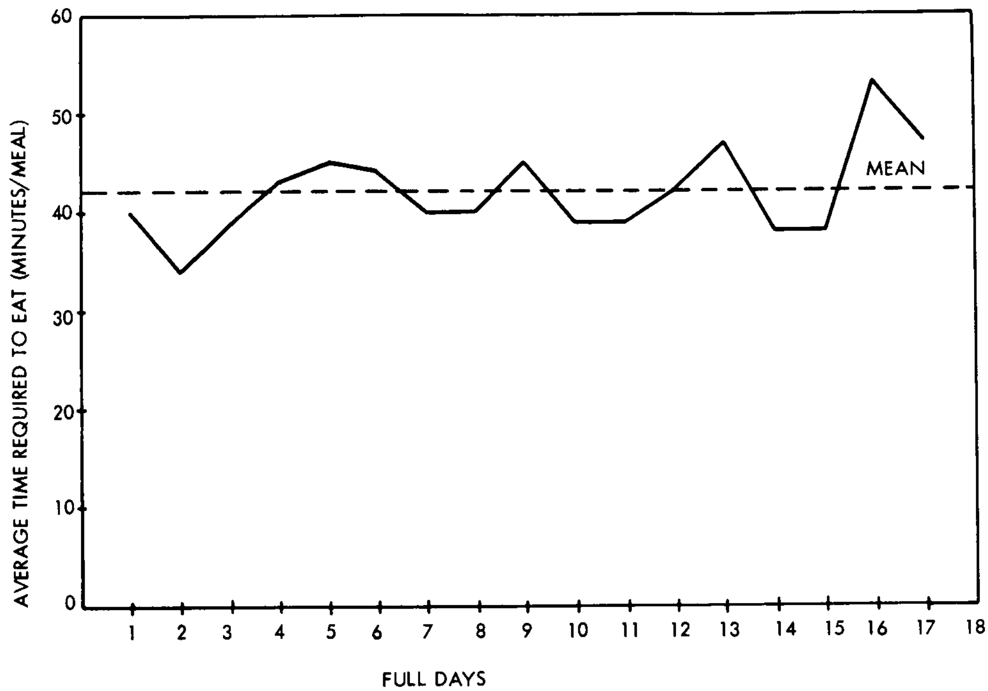
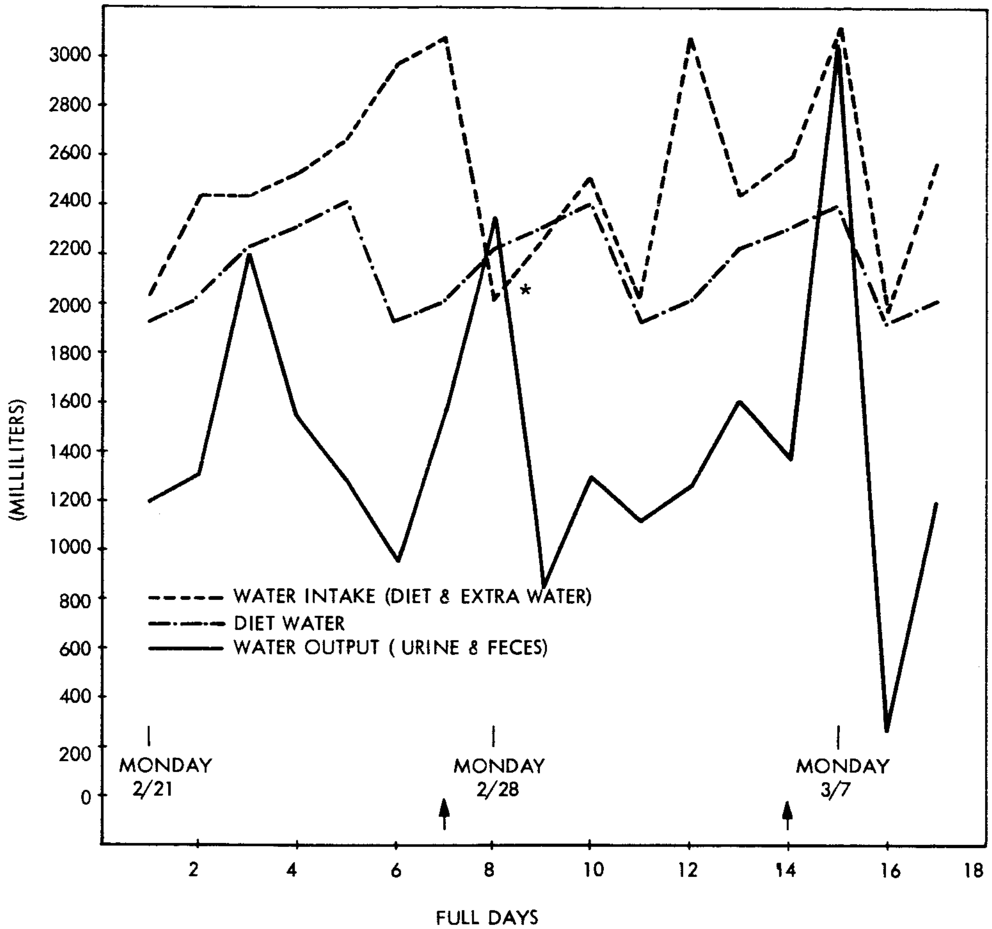
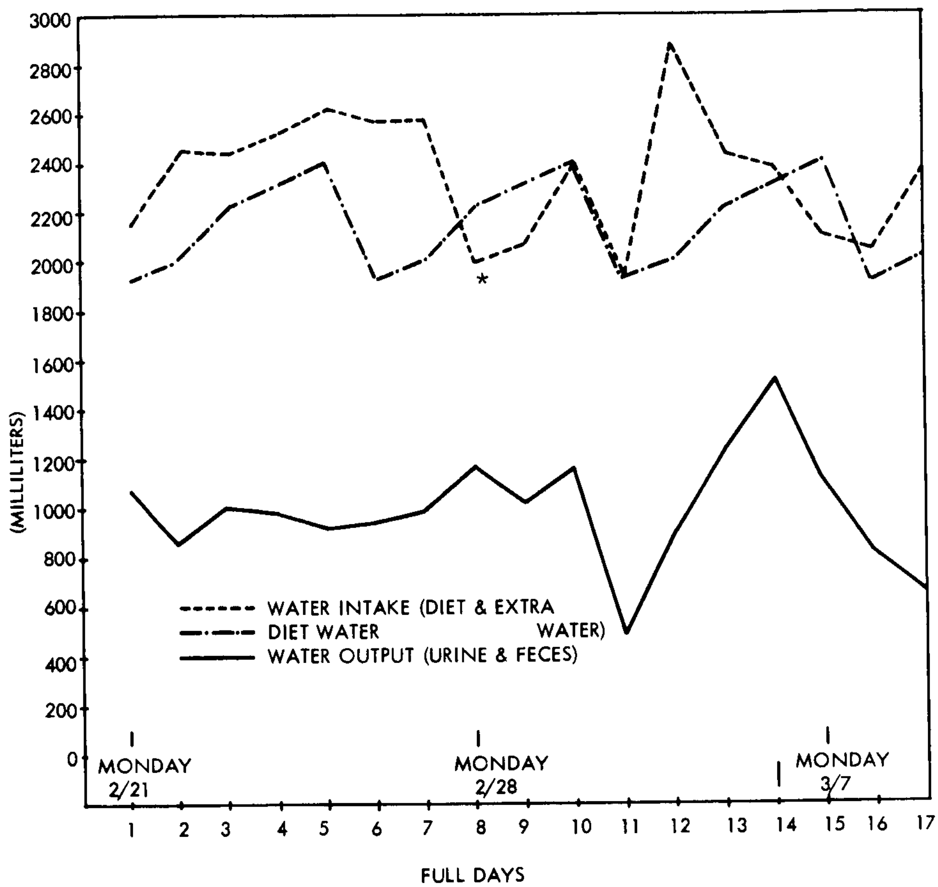


Figure 76. Meal Consumption Times versus Days in Simulator



* DIET WATER EXCEEDS WATER INTAKE ON DAYS WHEN SPECIFIC FLUID ITEMS PRESCRIBED BY THE DIET WERE DELETED.

Figure 77. Water Exchanges - Operator 1



* DIET WATER EXCEEDS WATER INTAKE ON DAYS WHEN SPECIFIC FLUID ITEMS PRESCRIBED BY THE DIET WERE DELETED.

Figure 78. Water Exchanges - Operator 2

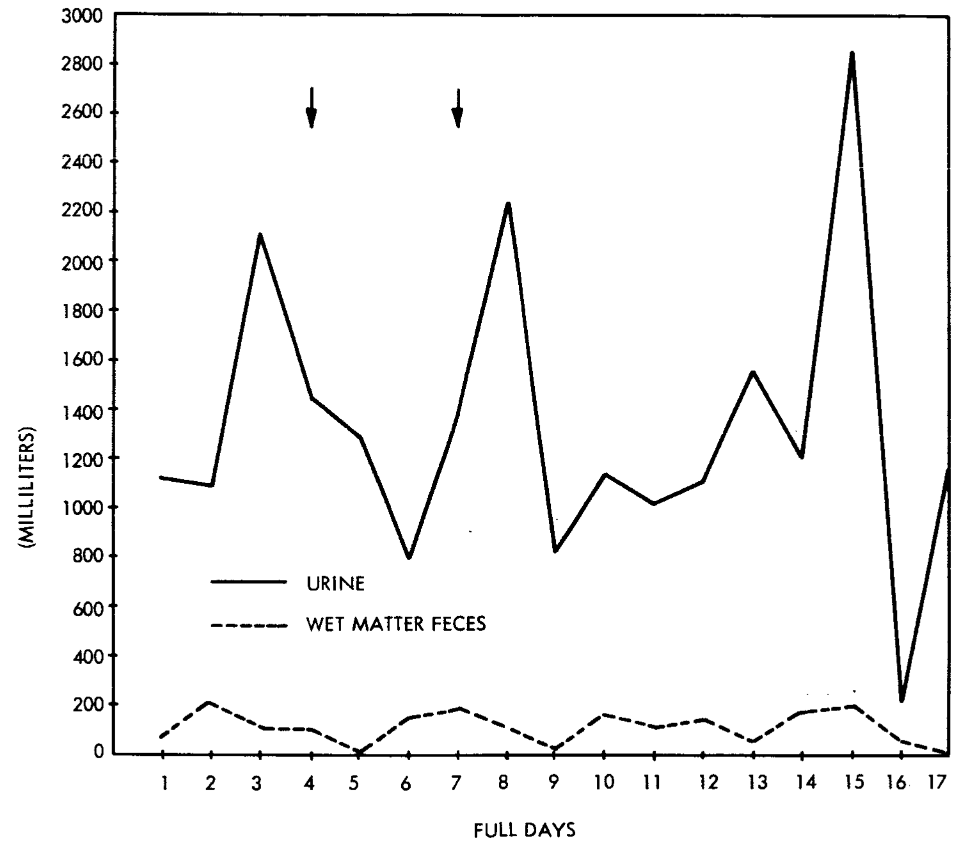


Figure 79. Measured Water Output - Operator 1

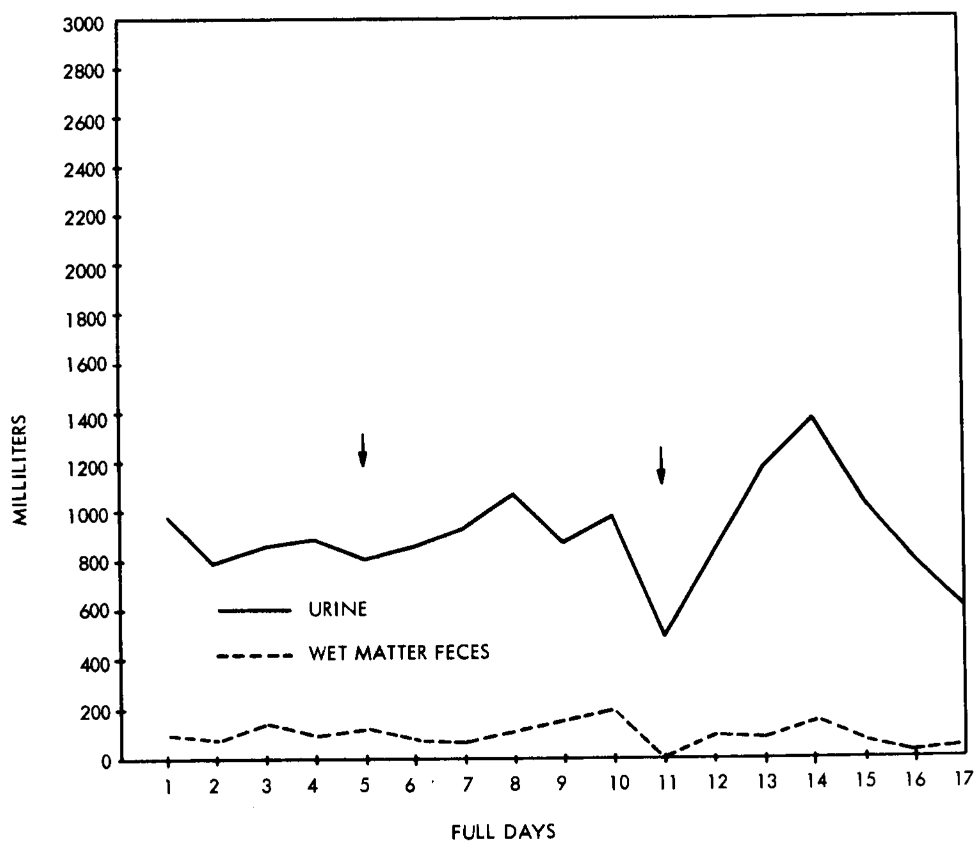


Figure 80. Measured Water Output - Operator 2

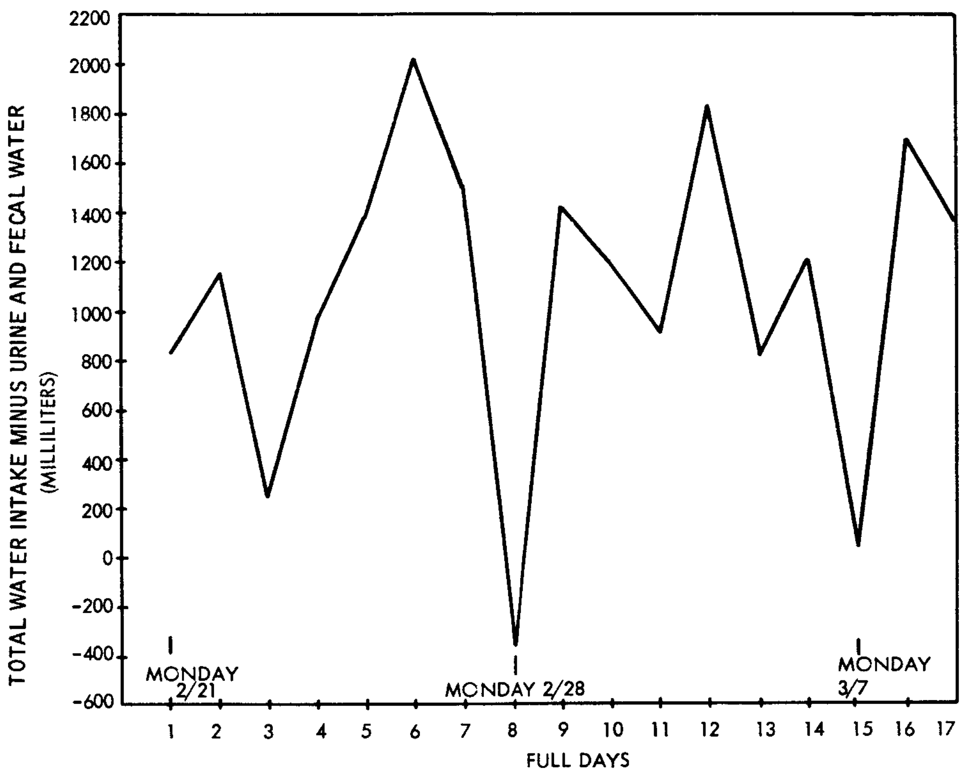


Figure 81. Total Water Intake Minus Urine and Fecal Water - Operator 1

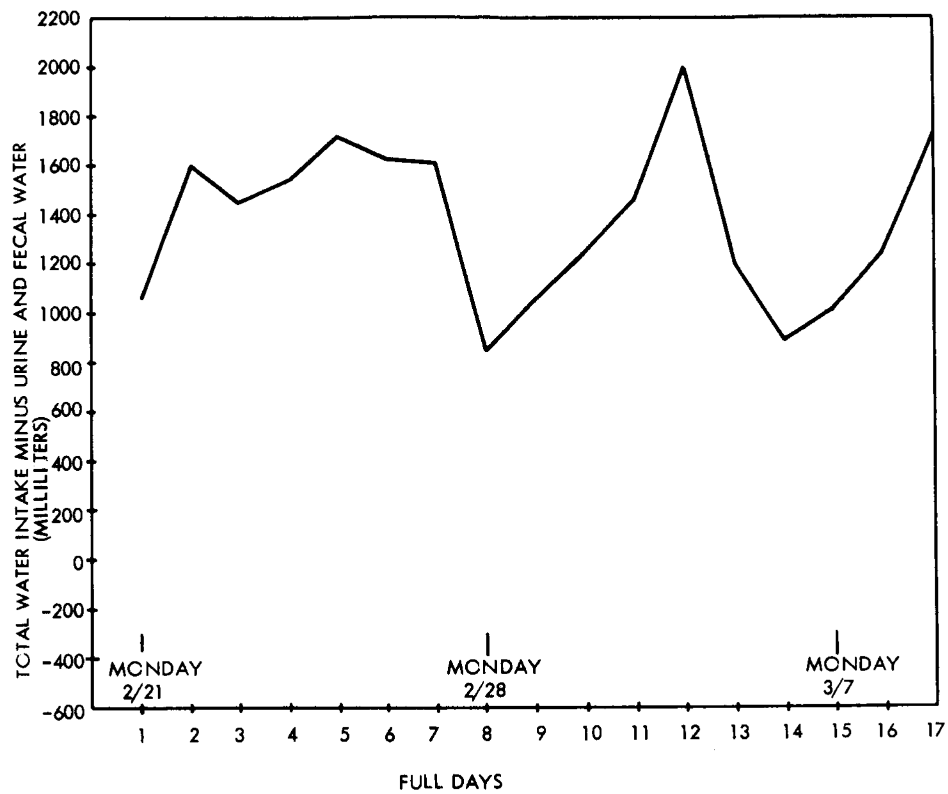


Figure 82. Total Water Intake Minus Urine and Fecal Water - Operator 2

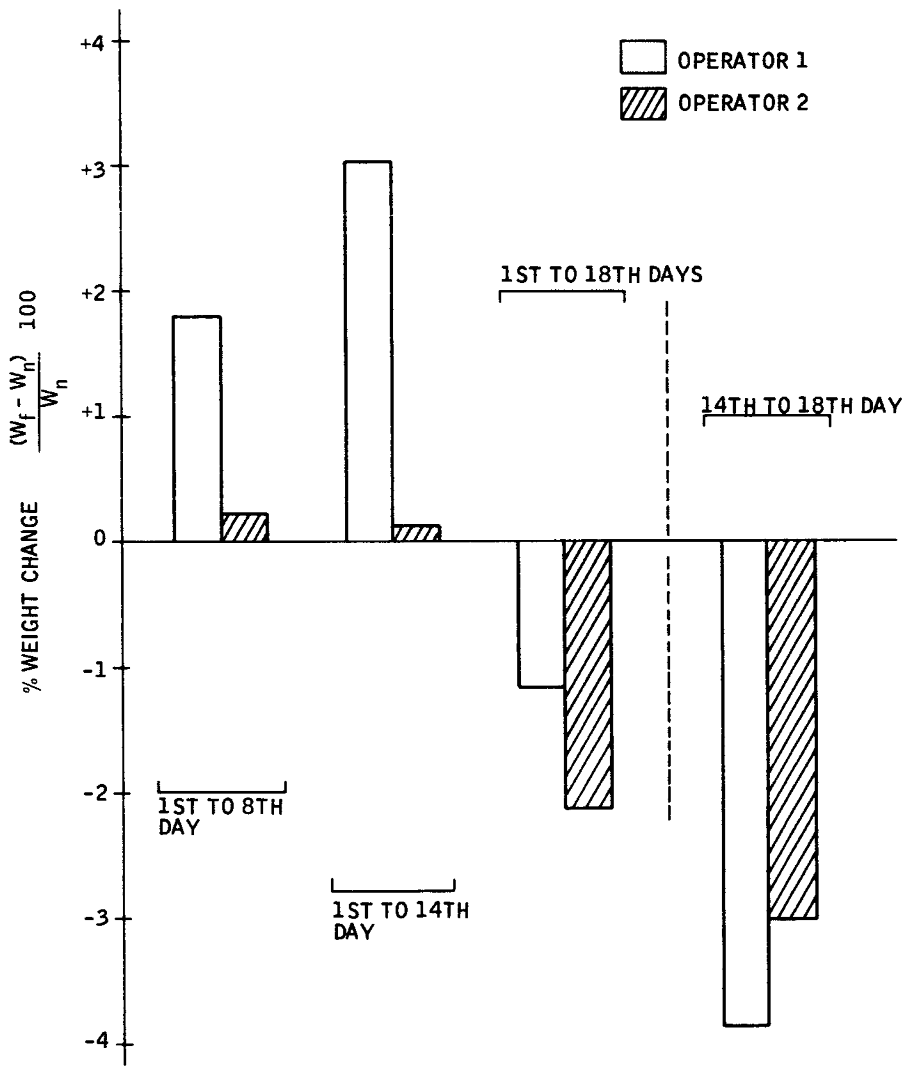


Figure 83. Percent Weight Changes (note magnified scale)

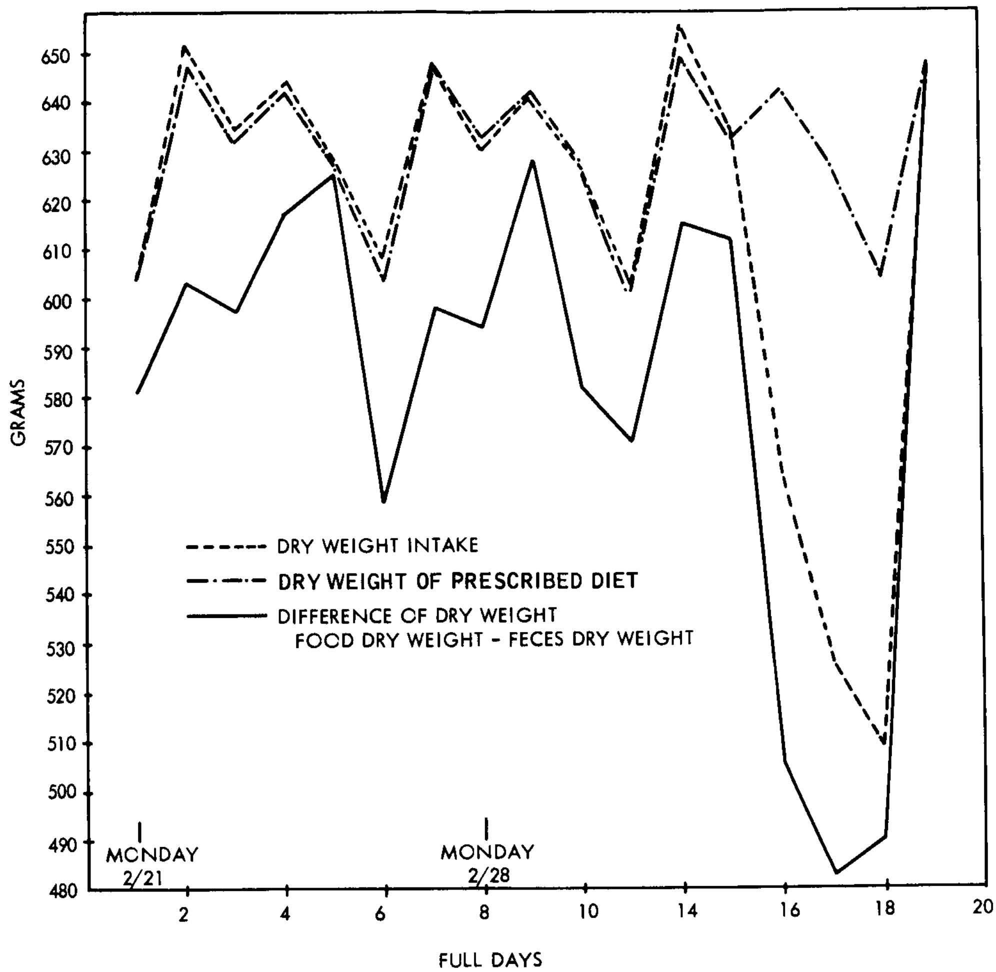


Figure 84. Dry Weight Exchanges - Operator 1

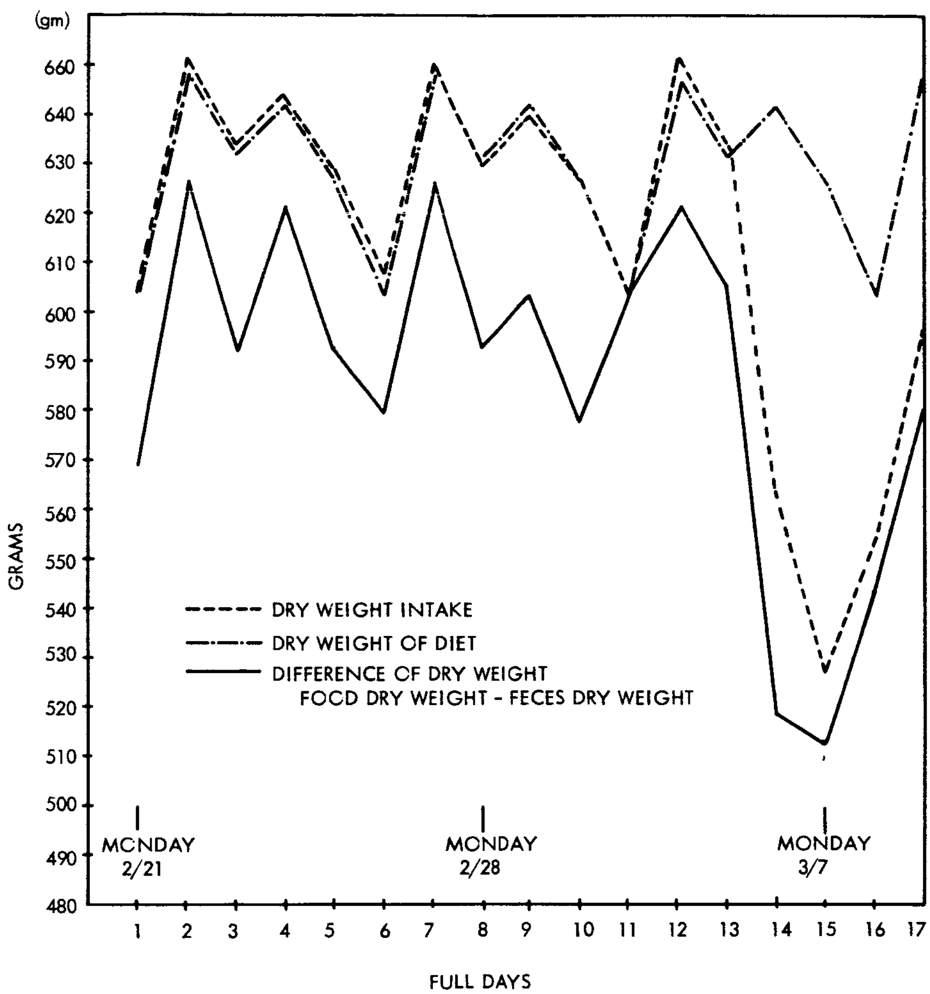


Figure 85. Dry Weight Exchanges - Operator 2

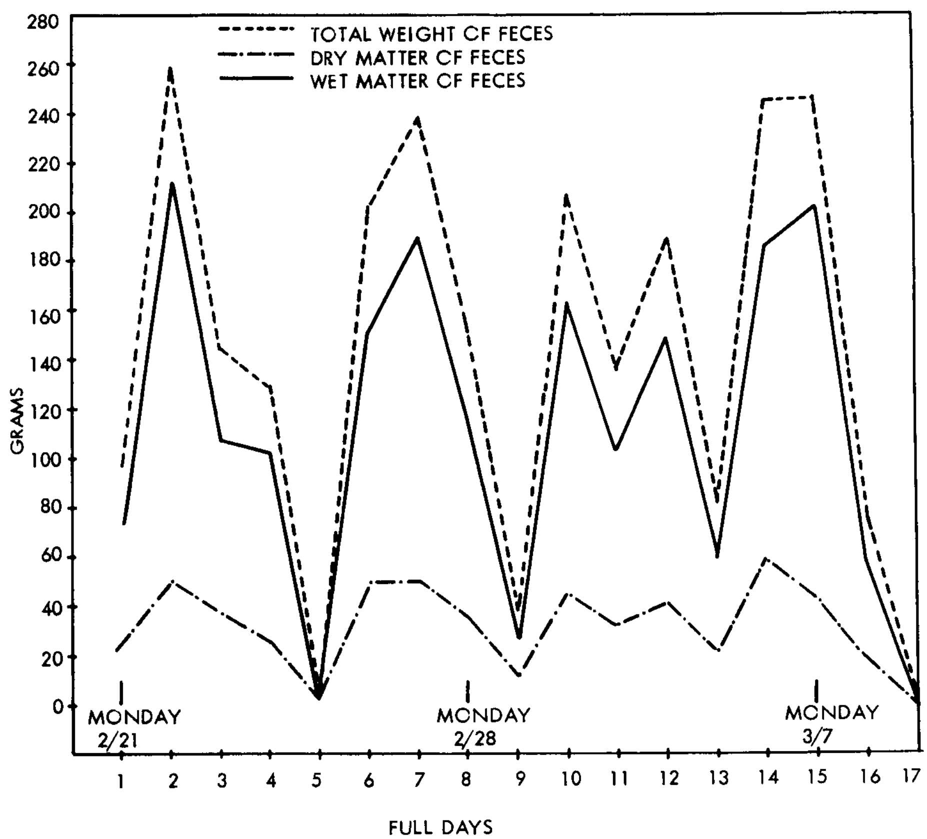


Figure 86. Feces Generation - Operator 1

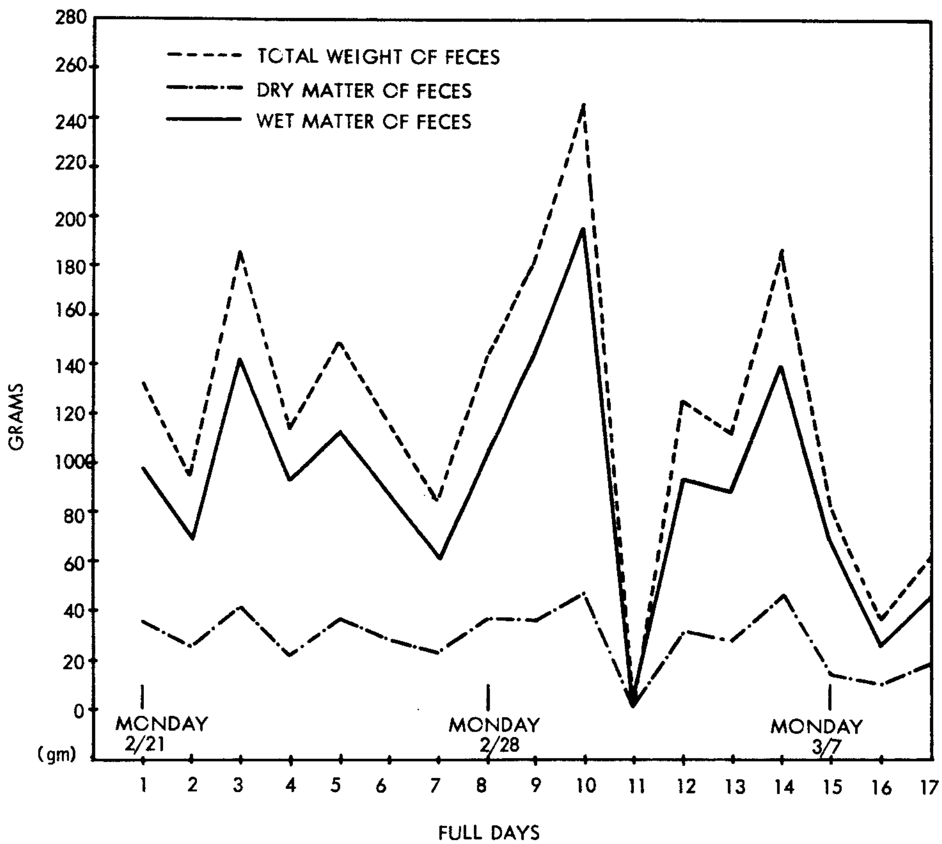


Figure 87. Feces Generation - Operator 2

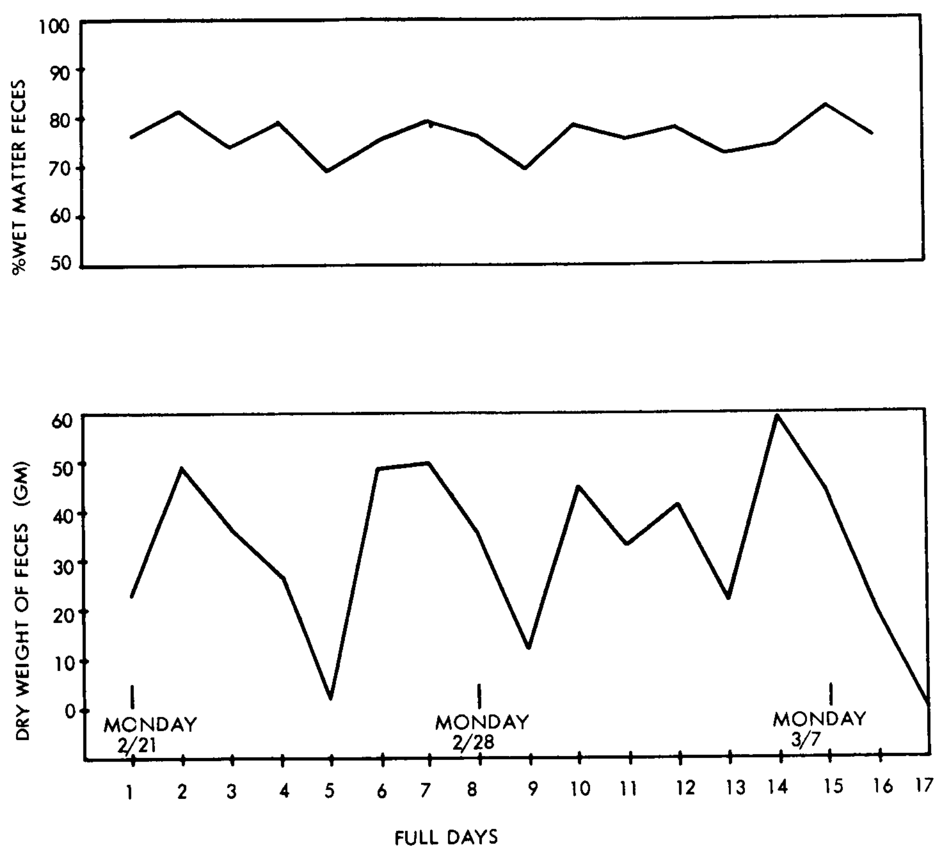


Figure 88. Dry Weight and Percent Water Content of Feces - Operator 1

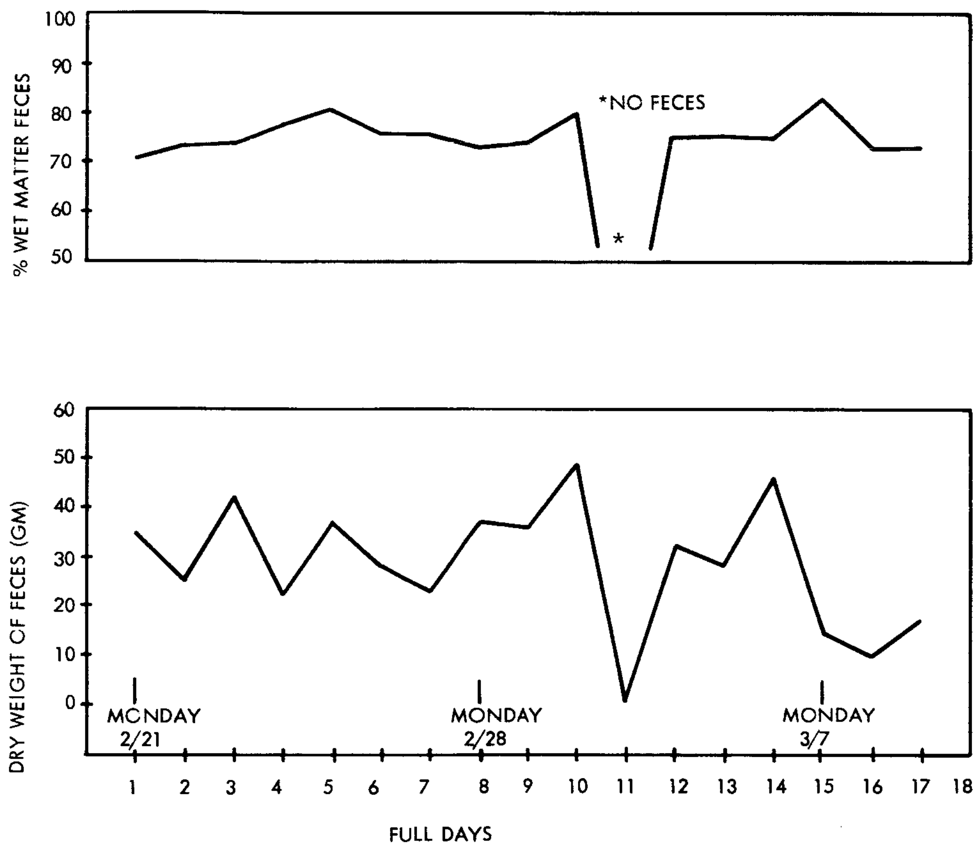


Figure 89. Dry Weight and Percent Water Content of Feces - Operator 2

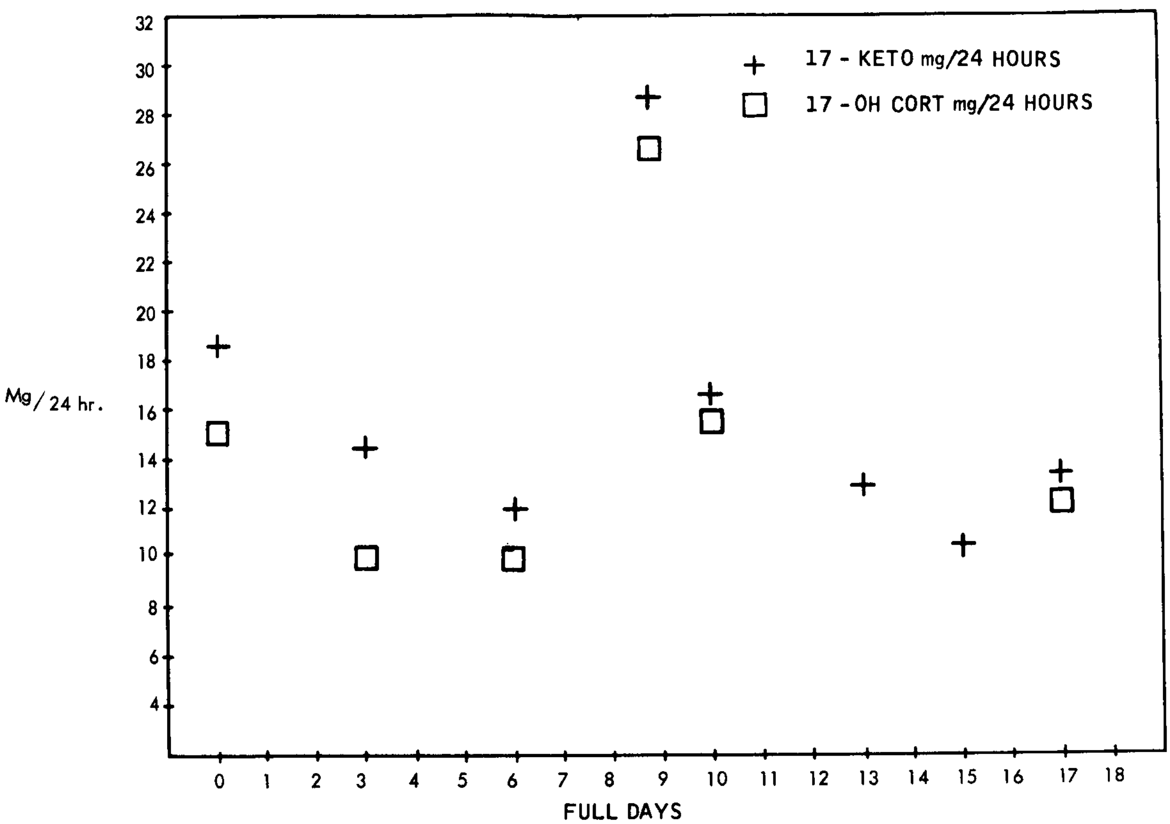


Figure 90. Urine Hormone Output - Operator 1

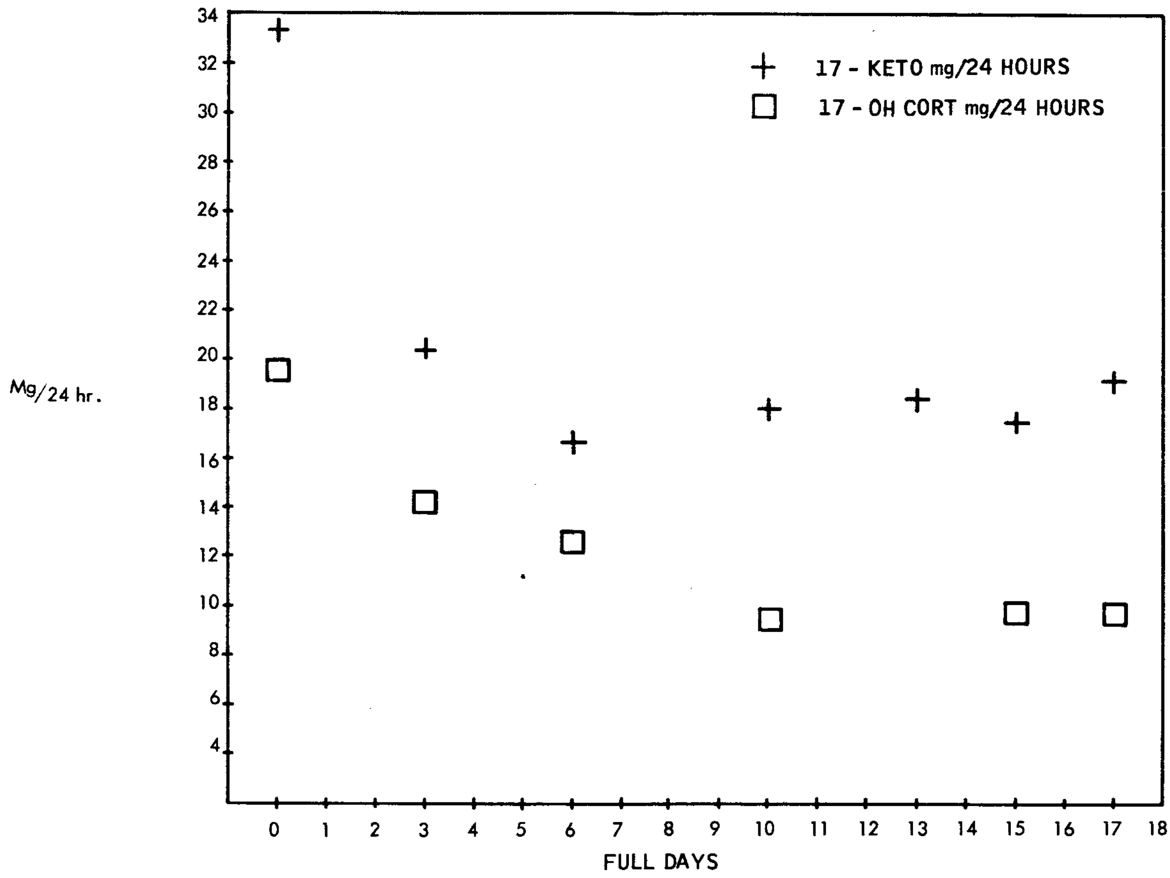


Figure 91. Urine Hormone Output - Operator 2

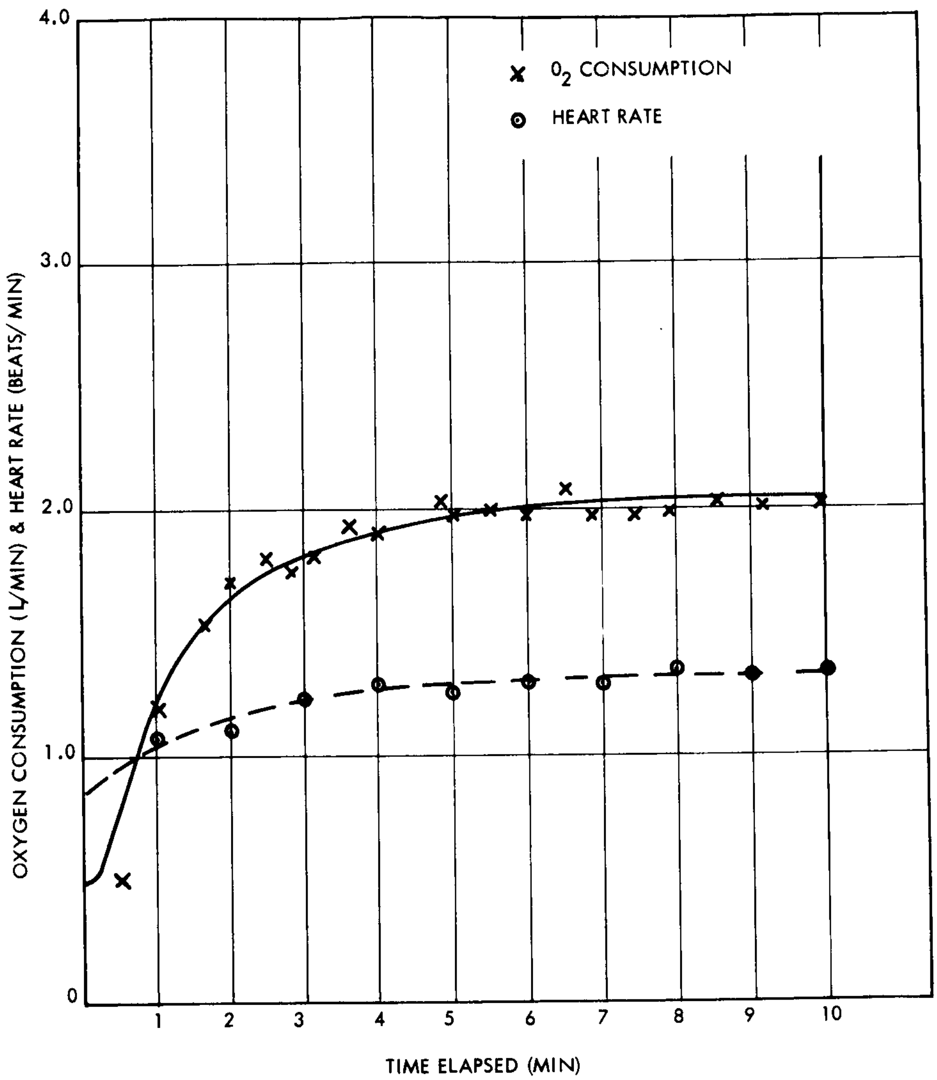


Figure 92. Heart Rate and Oxygen Consumption During Submaximal Work - Operator 1, Walk

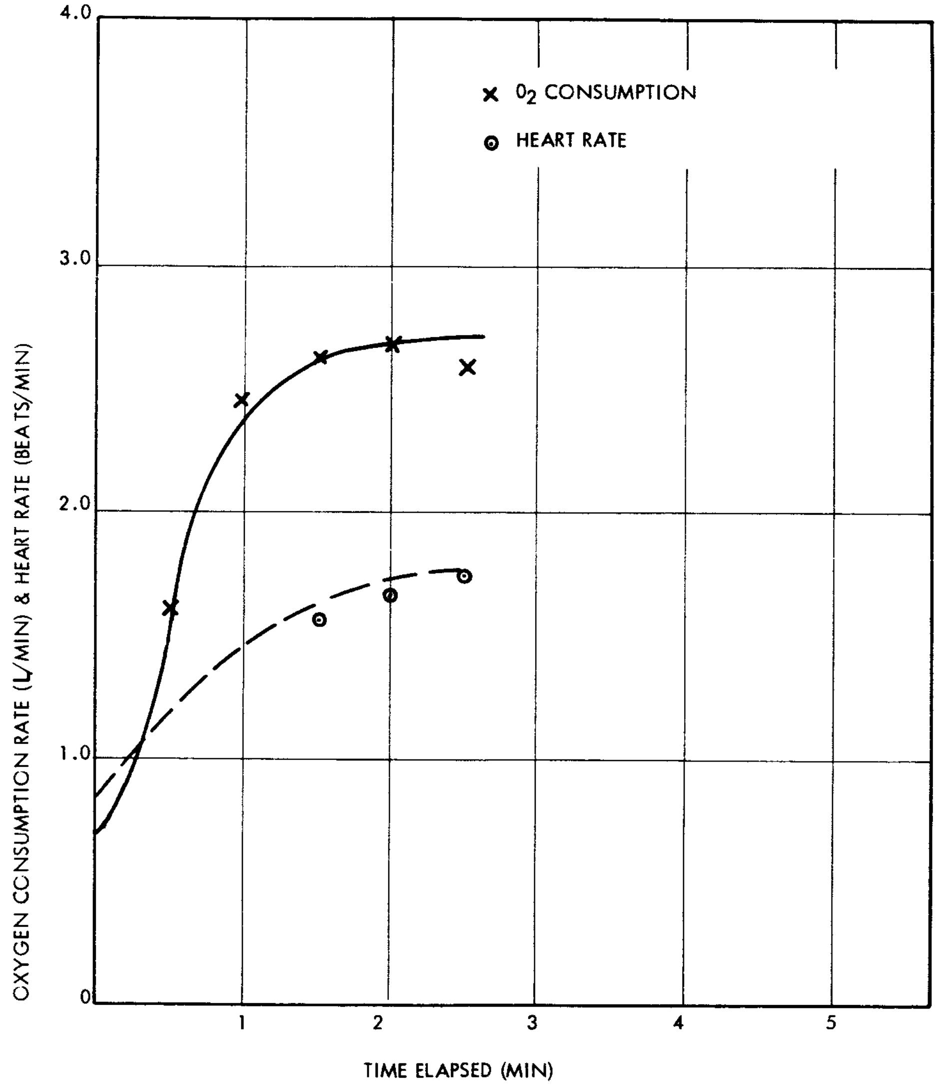


Figure 93. Heart Rate and Oxygen Consumption During Maximal Work - Operator 1, Run

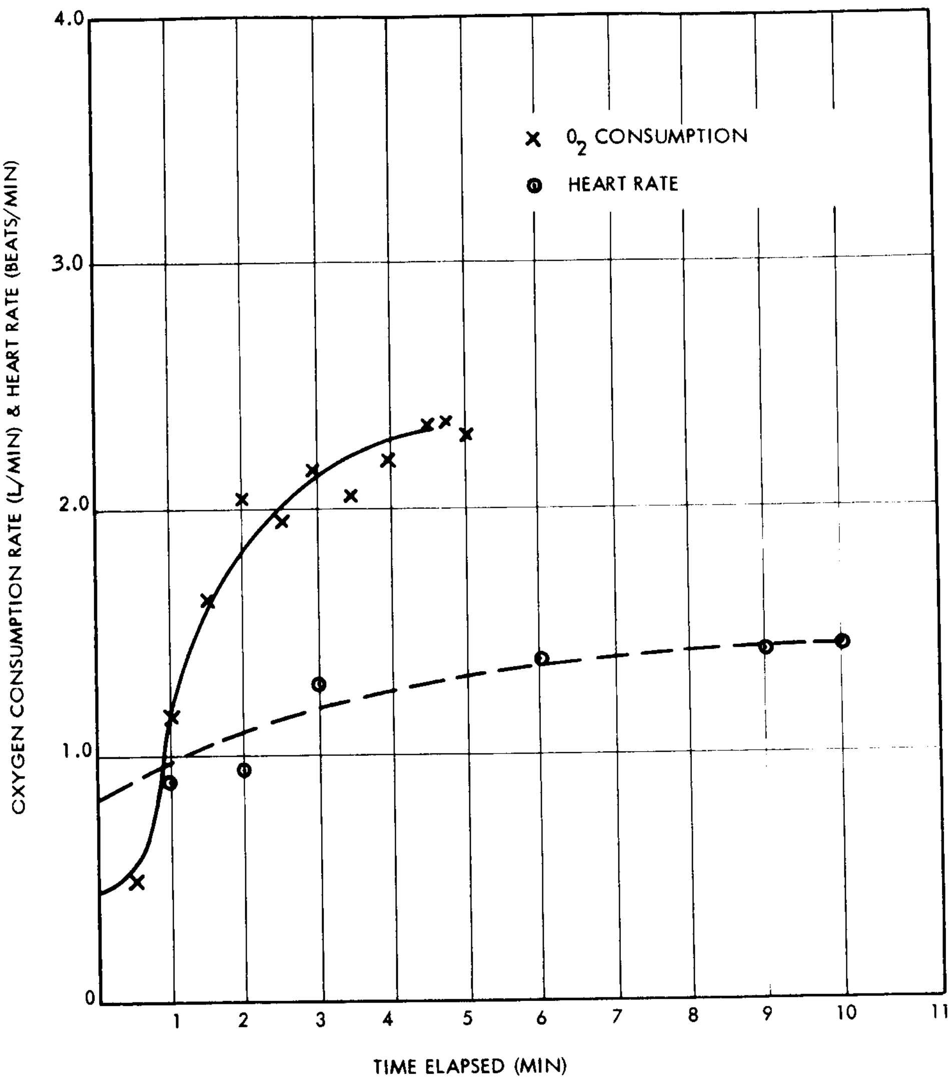


Figure 94. Heart Rate and Oxygen Consumption During Submaximal Work - Operator 2, Walk

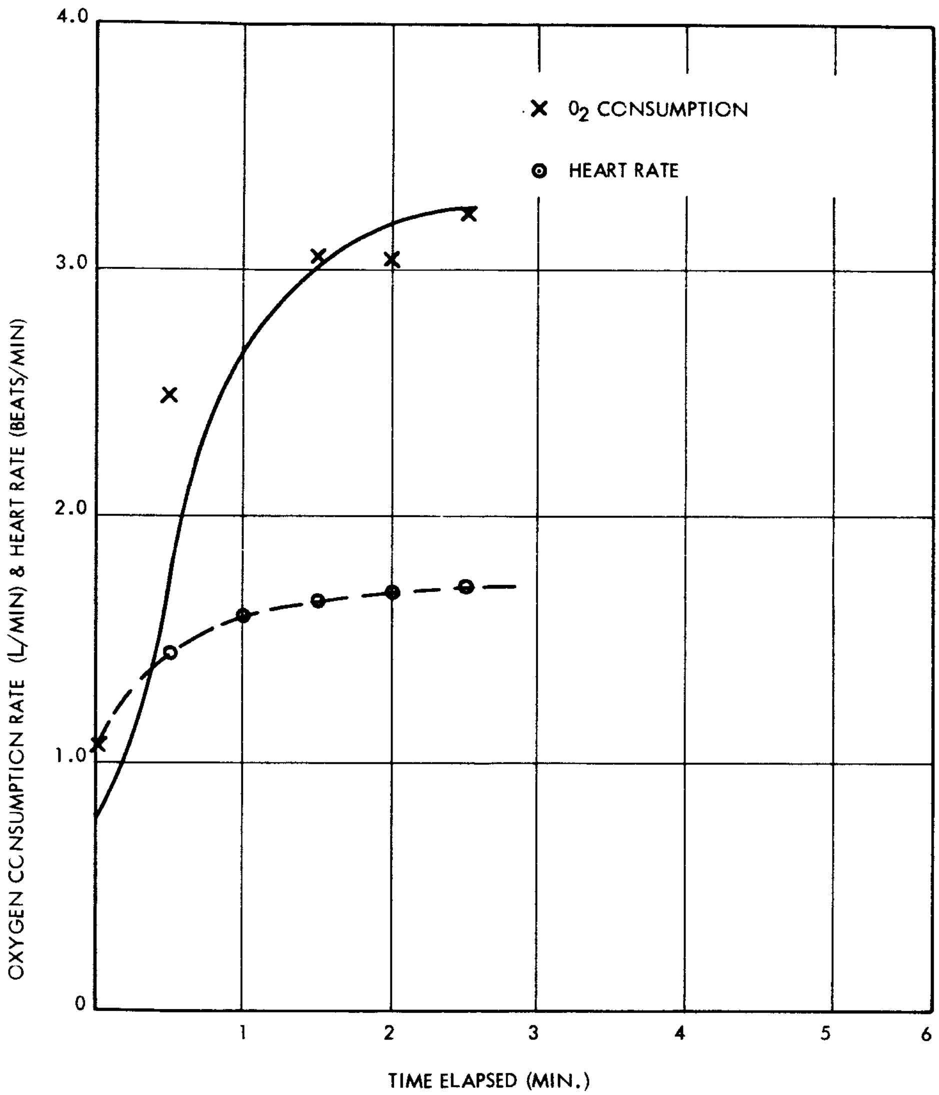


Figure 95. Heart Rate and Oxygen Consumption During Maximal Work - Operator 2, Run

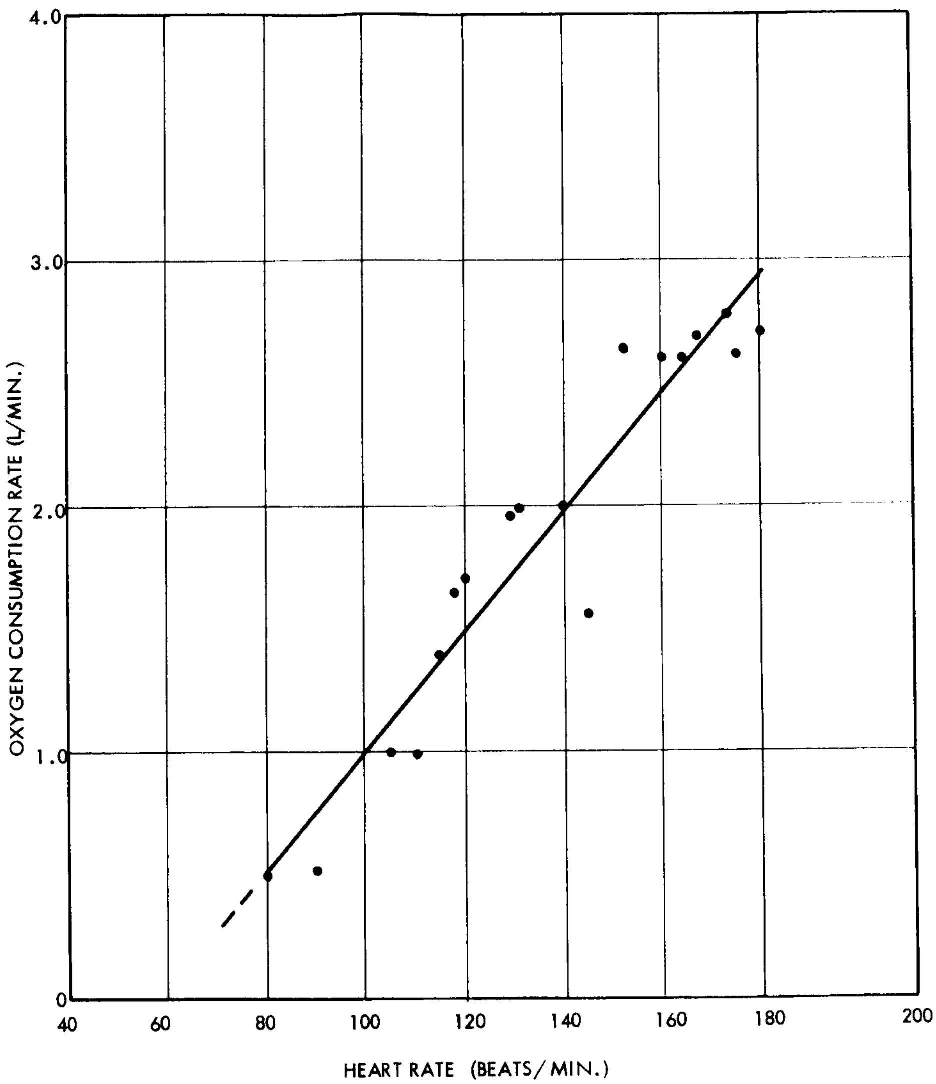


Figure 96. Relationship of Oxygen Consumption and Heart Rate - Operator 1

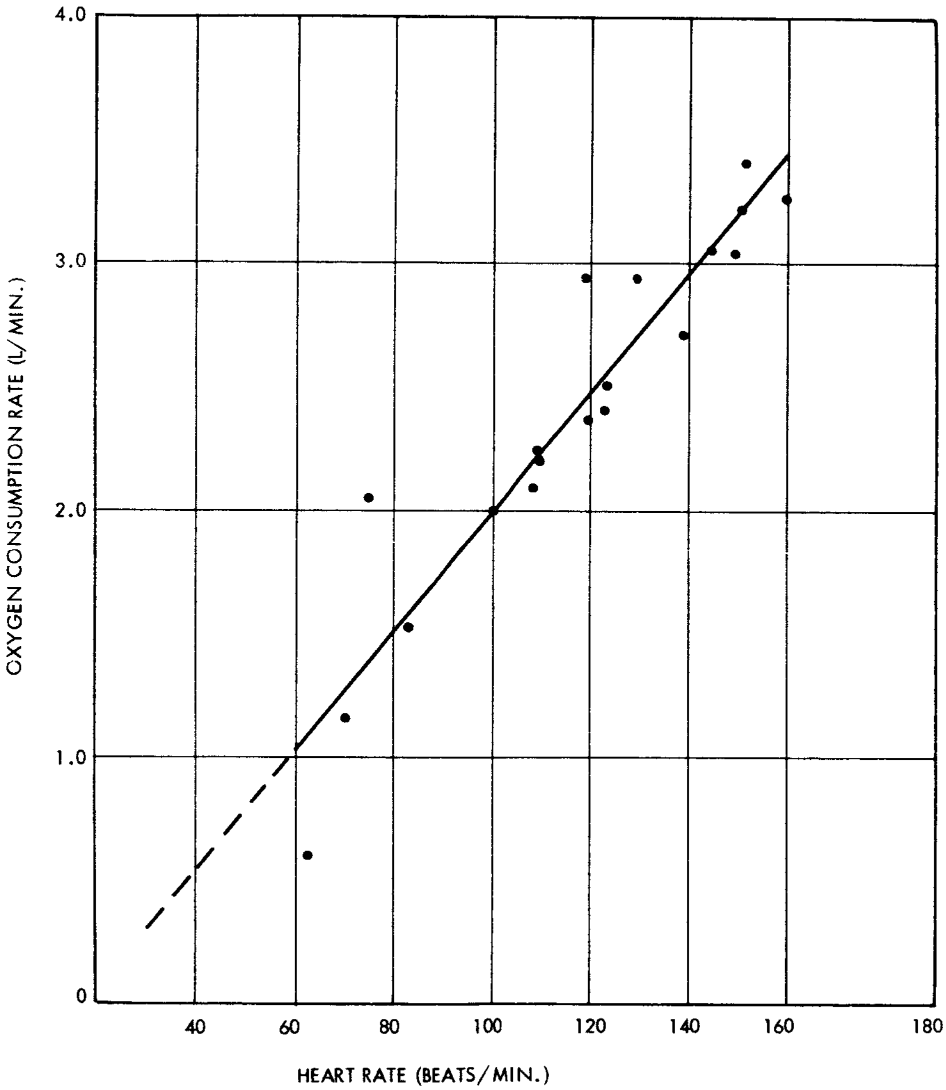


Figure 97. Relationship of Oxygen Consumption and Heart Rate - Operator 2

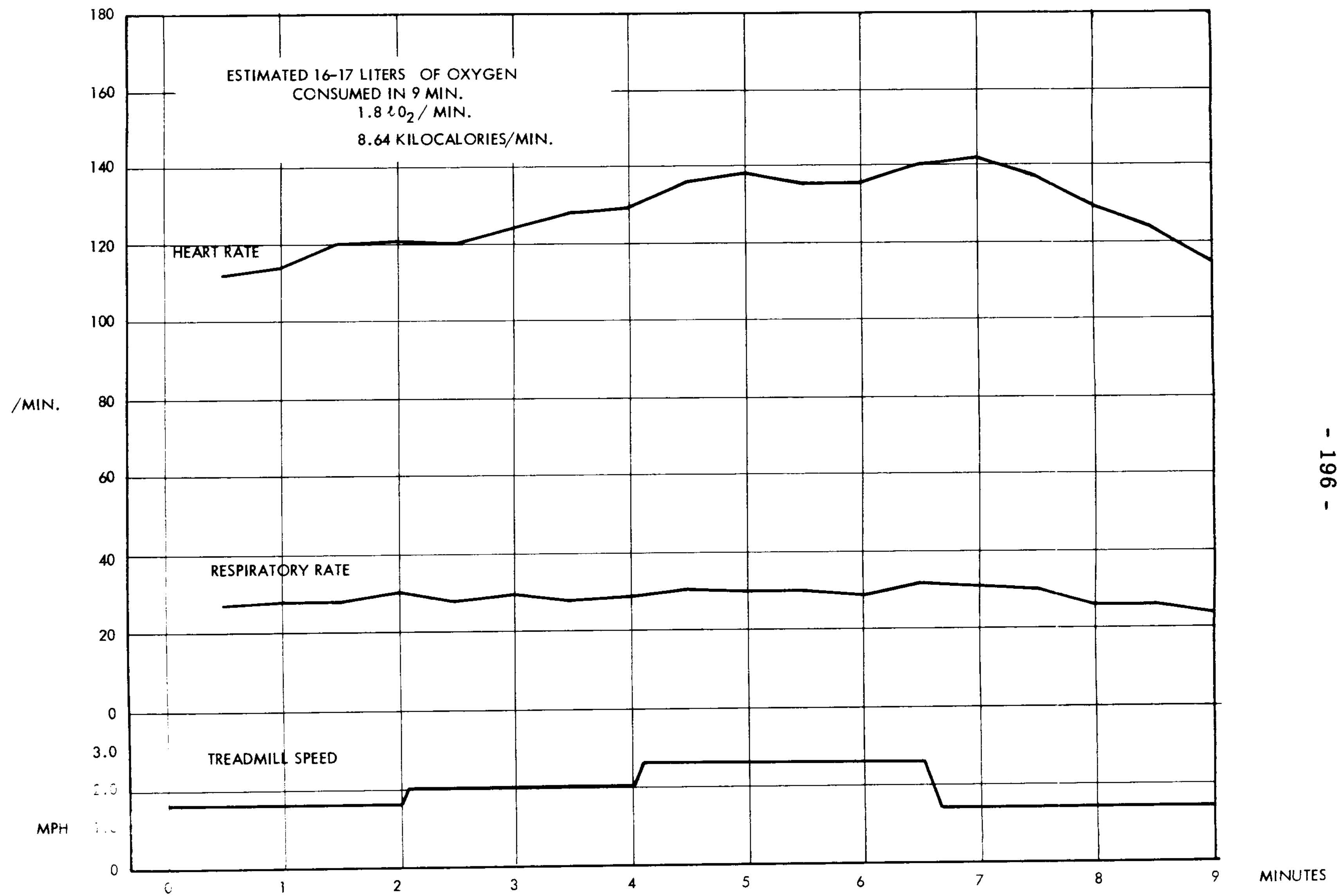


Figure 98. Treadmill Profile at 4-Percent Grade - Operator 1; 12 Full Days in Simulator

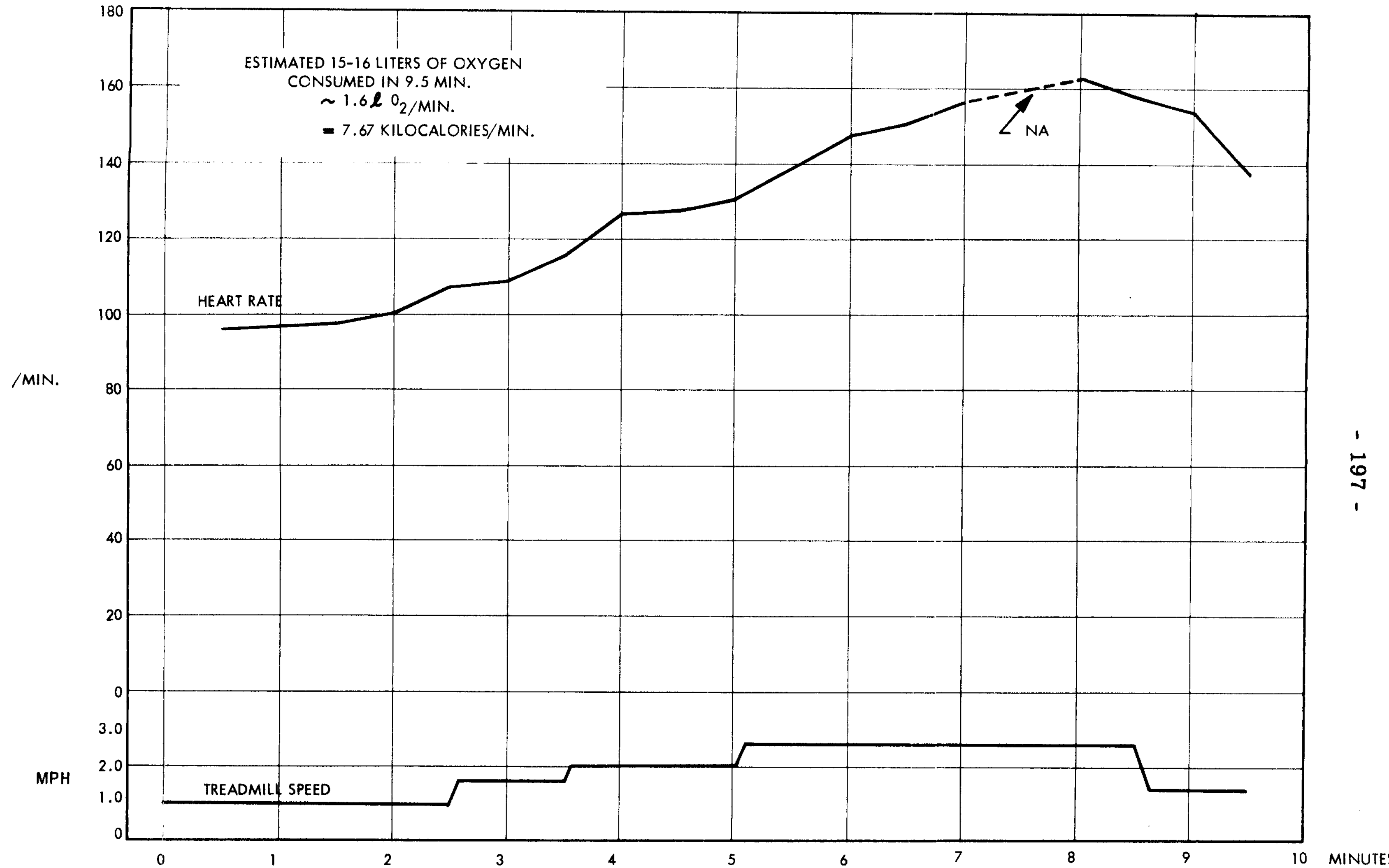


Figure 99. Treadmill Profile at 4-Percent Grade - Operator 1; 14 Full Days in Simulator (respiratory rate not recorded)

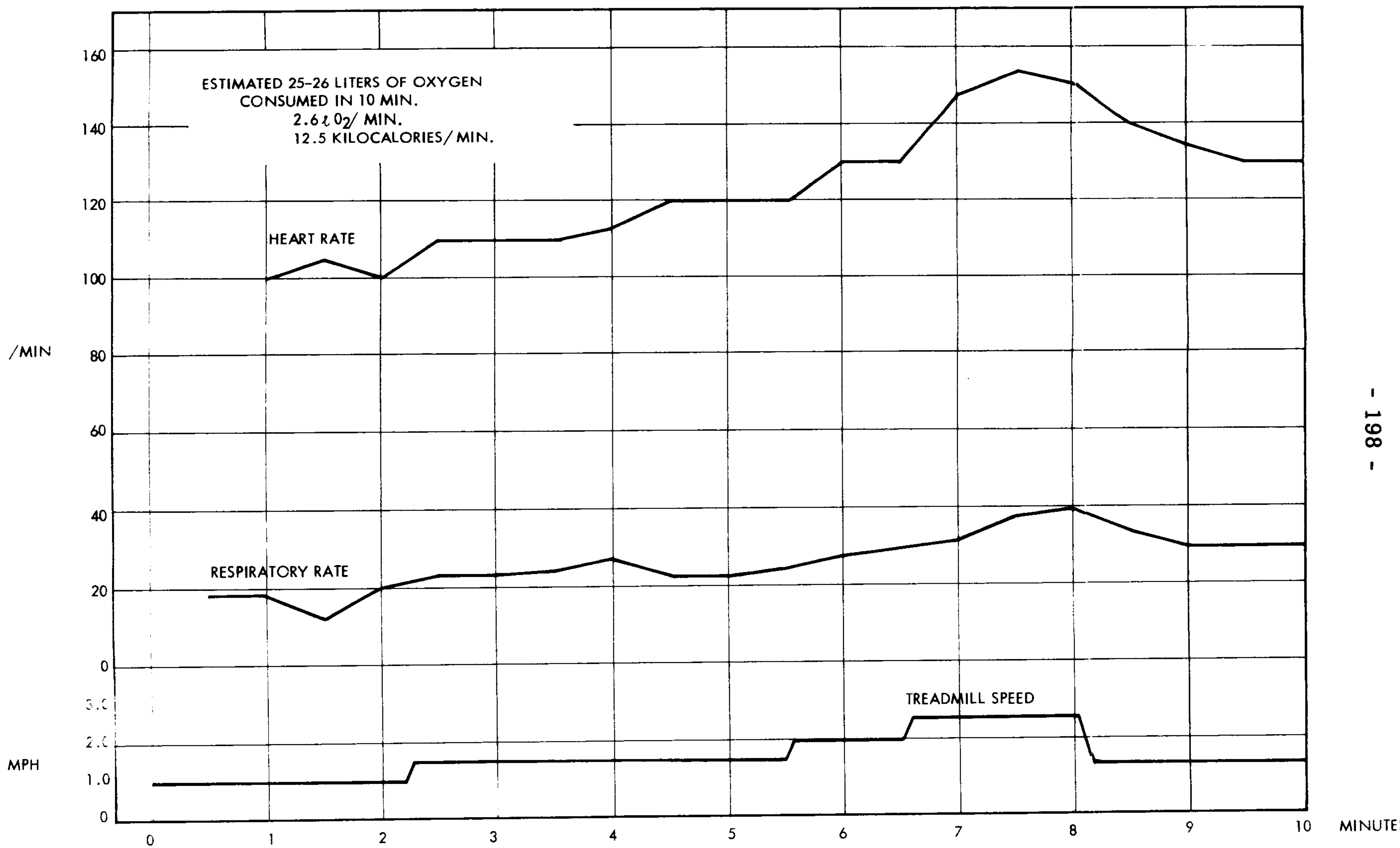


Figure 100. Treadmill Profile at 4-Percent Grade - Operator 2; 9 Full Days in Simulator

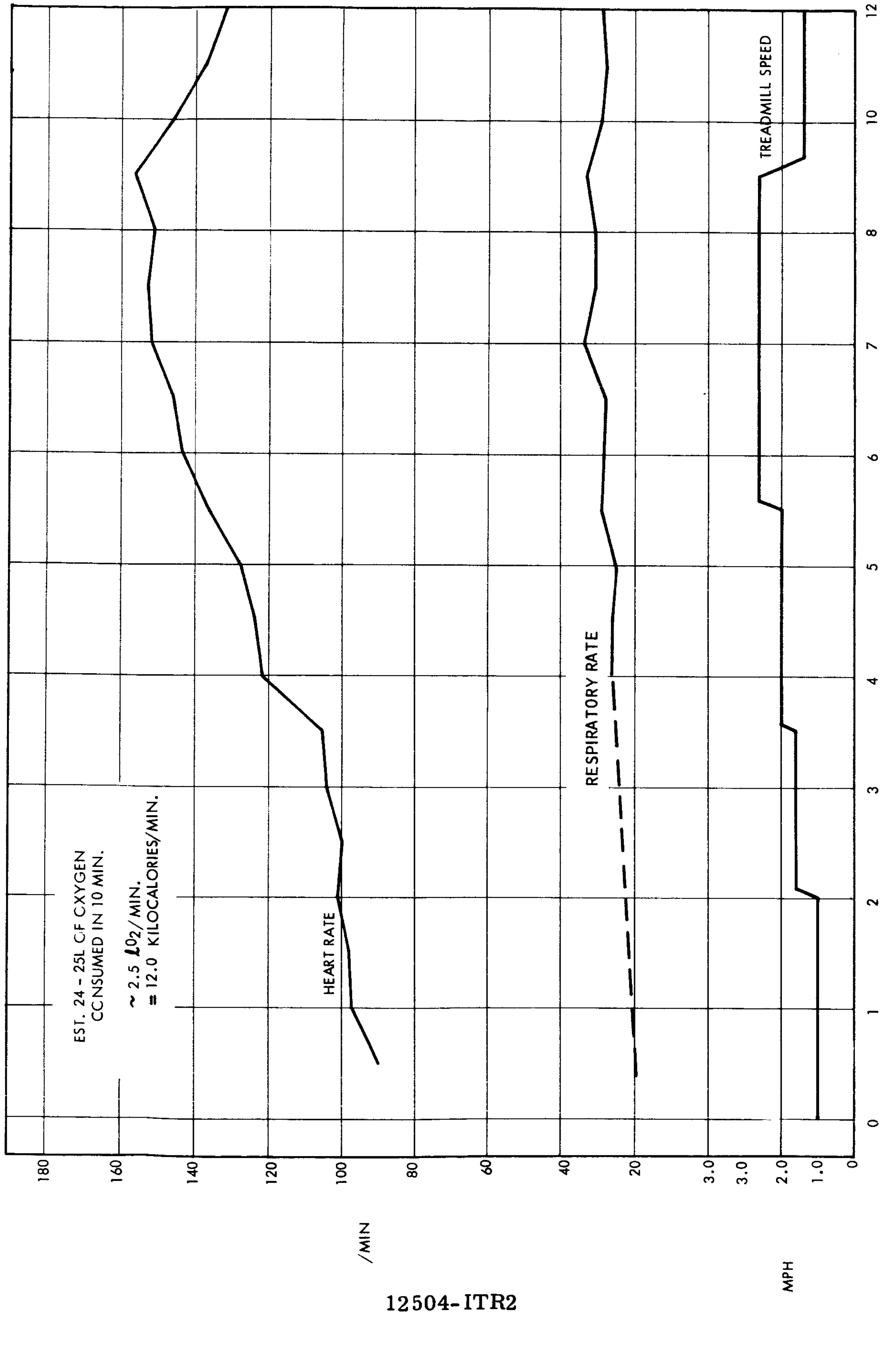


Figure 101. Treadmill Profile at 4-Percent Grade - Operator 2; 15 Full Days in Simulator (respiratory rate not recorded for first 4 minutes)

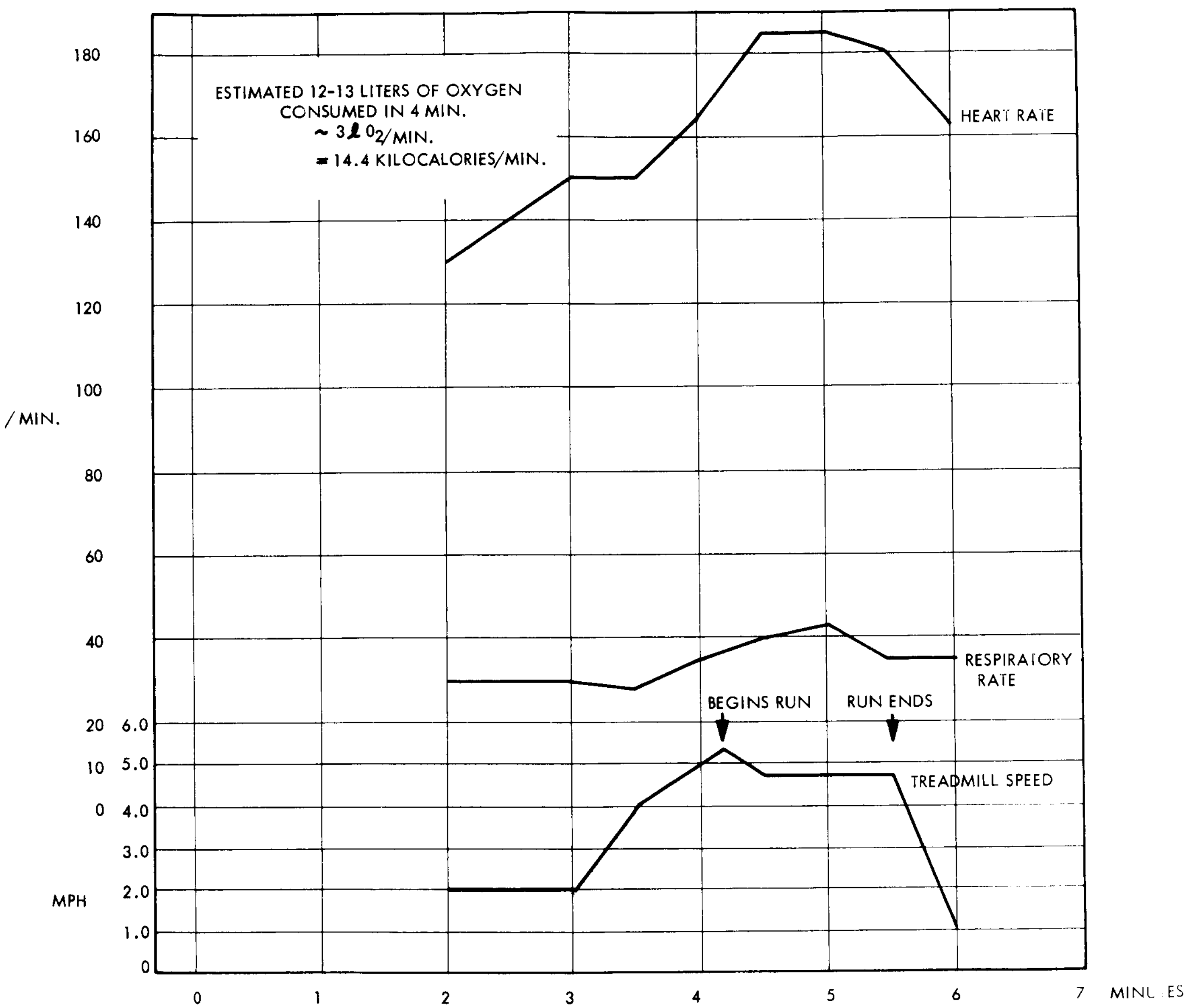


Figure 102. Treadmill Profile at 4-Percent Grade - Operator 2; 17 Full Days in Simulator

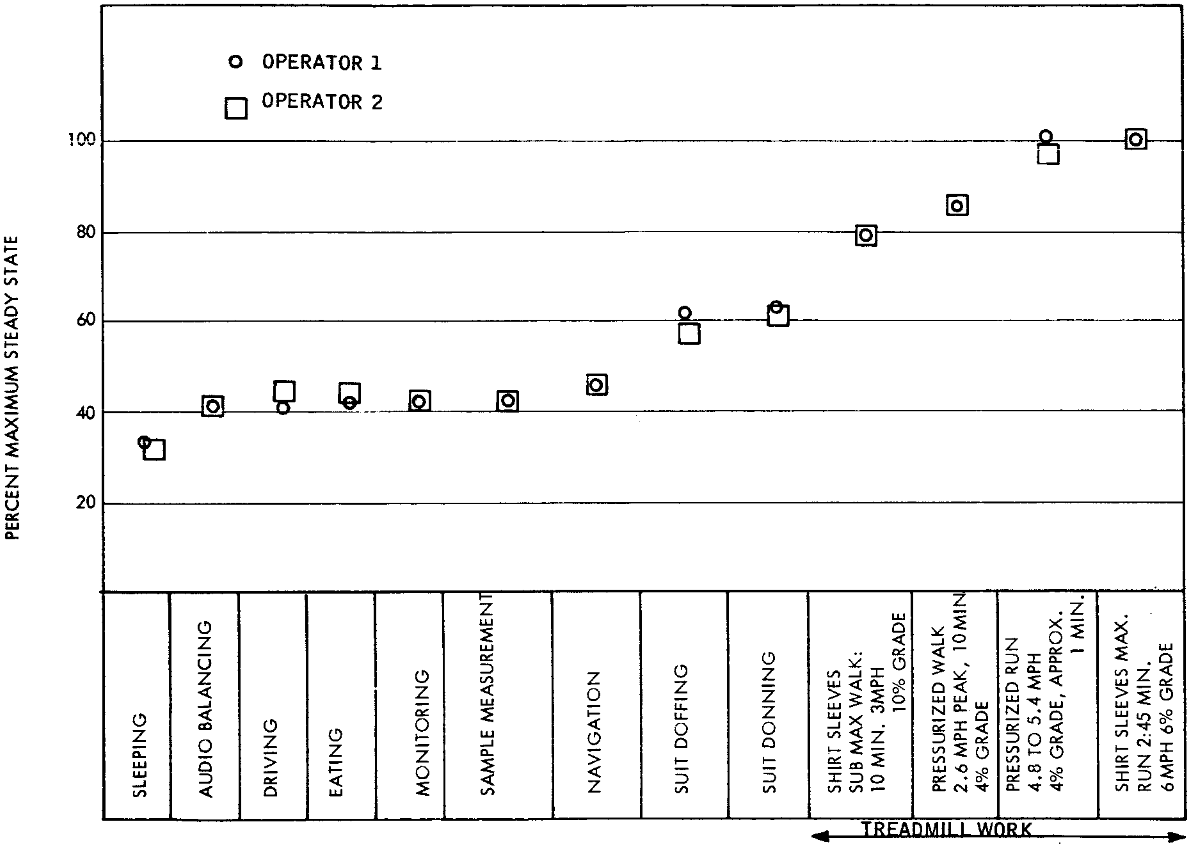


Figure 103. Mean Heart Rate Task Profiles as a Percent of Maximum Work - (P/P_C) 100

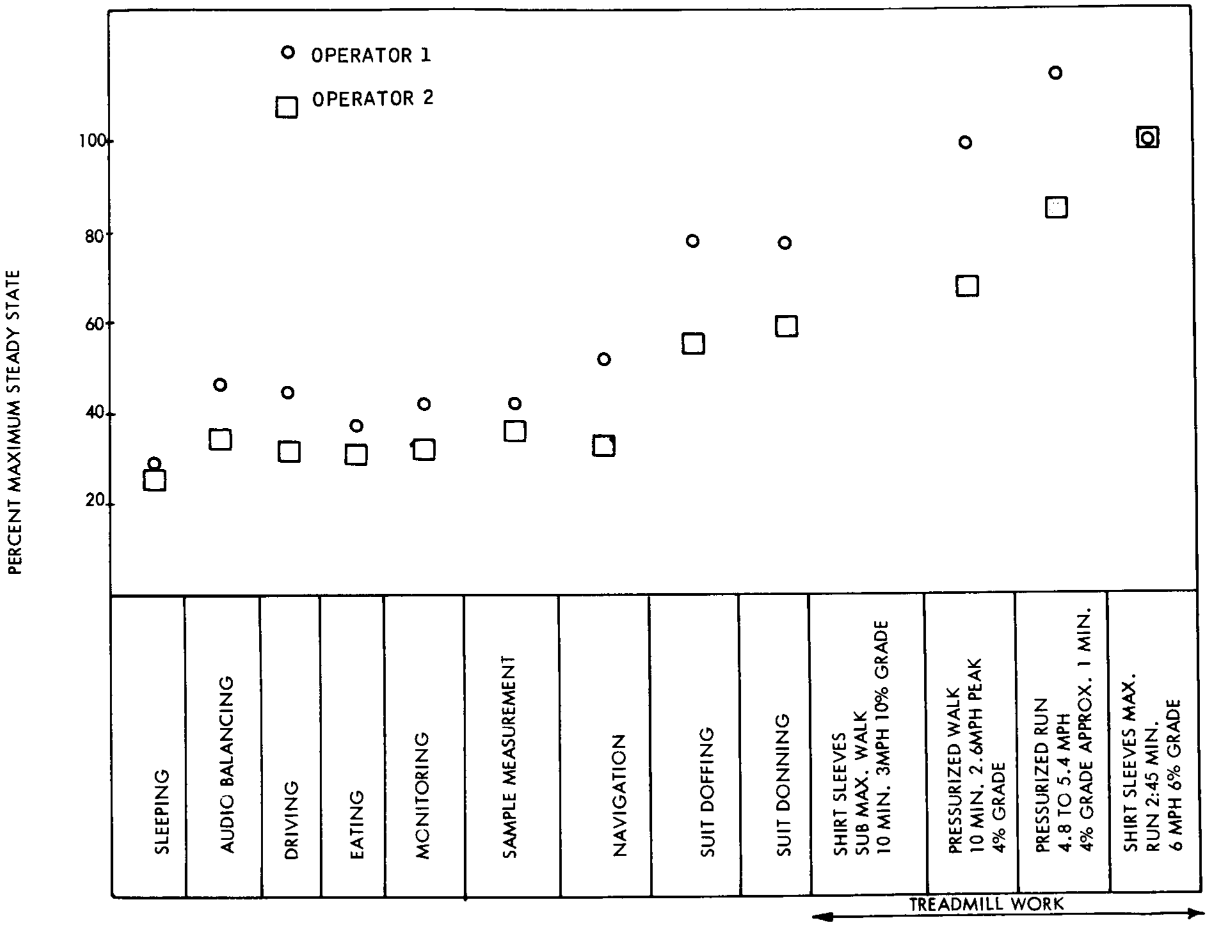


Figure 104. Mean Respiration Rate Task Profiles as a Percent of Maximum Work - (P/P_C) 100

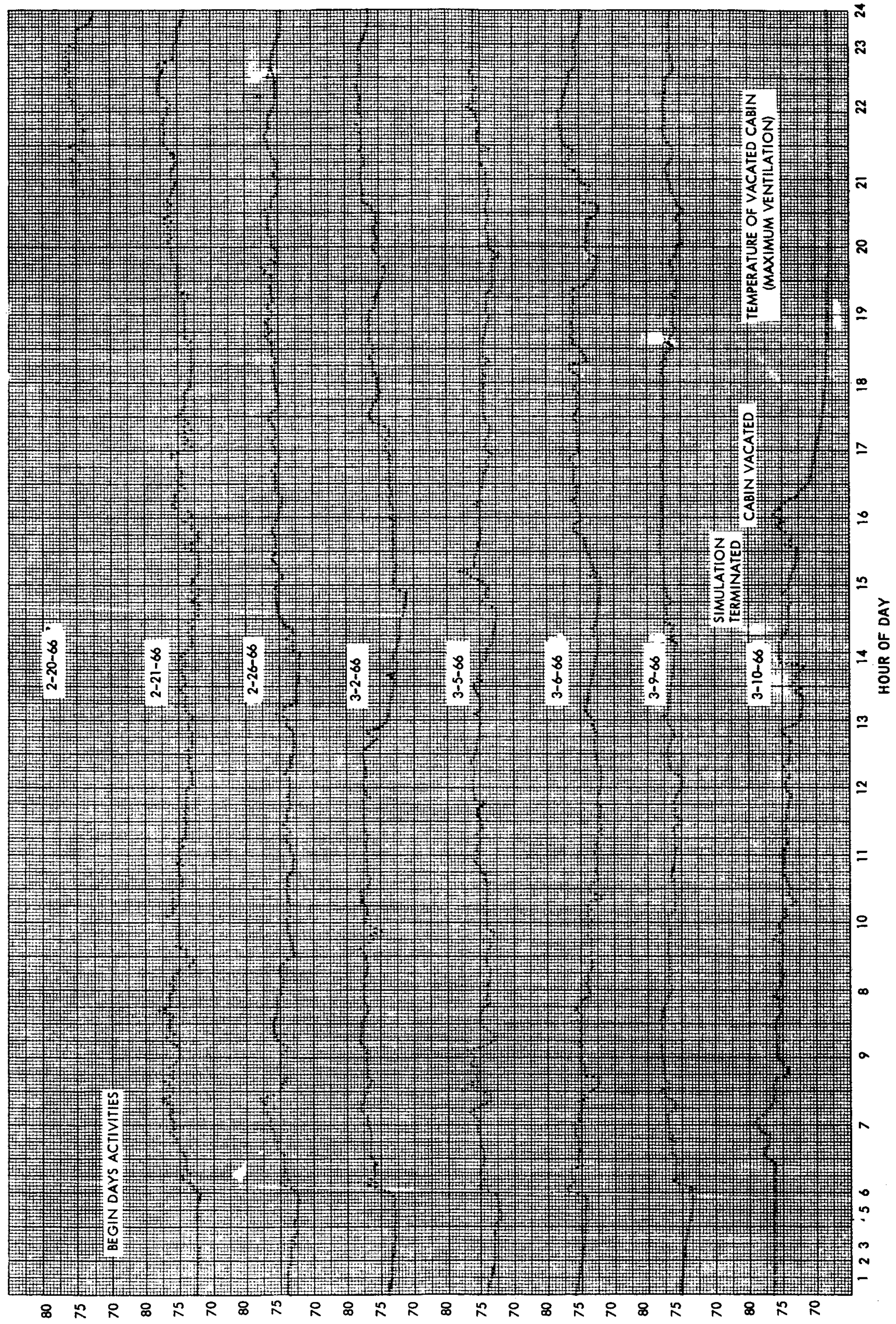


Figure 105. Daily Cabin Temperatures

Time of Day	Sequence A	Sequence B	Approximate Task Time (hr:min)
0600	Take down beds	Take down beds	:20
0620	Electrode checkout	Electrode checkout	:25
0645	Personal hygiene	Personal hygiene	:15
0720	Eat and cleanup	Eat and cleanup	:45
0750	Scientific tasks	Scientific tasks	:30
	Audio balancing	Sample measurement	
	Suit checkout	Audio balancing	
0820	Suit don	Suit don	:55
0915	Outside tasks	Inside tasks	:30
0945	Suit off	Suit off	:55
1040	Drive	Monitor	1:00
1140	Chart (if required)	Navigate	:30
1210	Eat and hygiene	Eat and hygiene	:45
1255	Scientific task	Scientific task	1:00
	Audio balancing	Geophysical tasks (or suit checkout)	
	Sample measurement		
	(G P I set)	Audio balancing	
	Geophysical tasks	Sample measurements	
1355	Suit don	Suit don	:55
1450	Inside tasks (eg G P I set)	Outside task	:30
1520	Doff suit	Doff suit	:55
1615	Eat and hygiene	Eat and Hygiene	:45
1700	Monitor	Drive	1:00
1800	Navigate	Chart (if required)	:30
1830	Scientific tasks	Scientific tasks	1:00
	Sample measurement	Audio balancing	
	Audio balancing	Geophysical tasks	
	Geophysical tasks	Geophysical tasks	
1930	Buffer time period	Buffer time period	:30
2000	Eat and hygiene	Eat and hygiene	:40
2040	Scientific tasks	Scientific tasks	:50
	Sample measurement	Geophysical tasks	
	Geophysical tasks	Sample measurement	
2130	Remove electrodes	Remove electrodes	:05
2135	Hygiene	Hygiene	:15
2150	Set up beds	Set up beds	:10
2200	Retire	Retire	

Figure 106. Early LUNEX II Task Time Line

Time		Task Sequence	Approximate Task Time (hr:min)
0600	1	Take down beds	:20
0620	2	Electrode checkout	:15
0635	3	Eat (Meal 1) and cleanup	:45
0720	4	Hygiene	:20
0740	5	Drive/Monitor	1:00
0840	6	Chart (if required)/Navigate	:20
0900	7	Don suit and airlock pump down	:30
0930	8	Outside task and airlock pump up/inside tasks	:35
1005	9	Crew exchange and airlock pump down	:20
1025	10	Inside tasks/Outside tasks, airlock pump up	:35
1100	11	Doff, suit drying, cleanup	:45
1145	12	Eat (Meal 2) and cleanup	:45
1230	13	Rest period	1:00
1330	14	Sample measurements	:20
1350	15	Audio balancing	:20
1410	16	GPI/Suit checkout	:20
1430	17	Suit checkout/GPI	:20
1450	18	Monitor/Drive	1:00
1550	19	Navigate/Chart (if required)	:20
1610	20	Eat (Meal 3) and cleanup	:45
1655	21	Audio balancing	:20
1715	22	Sample measurements	:20
1735	23	Geophysical tasks	1:00
1835	24	Buffer period	:30
1905	25	Maintenance, repair and housekeeping	1:00
2005	26	Eat (Meal 4) and cleanup	:45
2050	27	Report writing, hygiene and personal activity	1:00
2150	28	Remove electrodes and set up beds	:10
2200	29	Retire	

Figure 107. Final LUNEX II Task Time Line

APPENDIX I

MISCELLANEOUS TASK DATA SUPPLEMENTAL TO TEXT DESCRIPTIONS

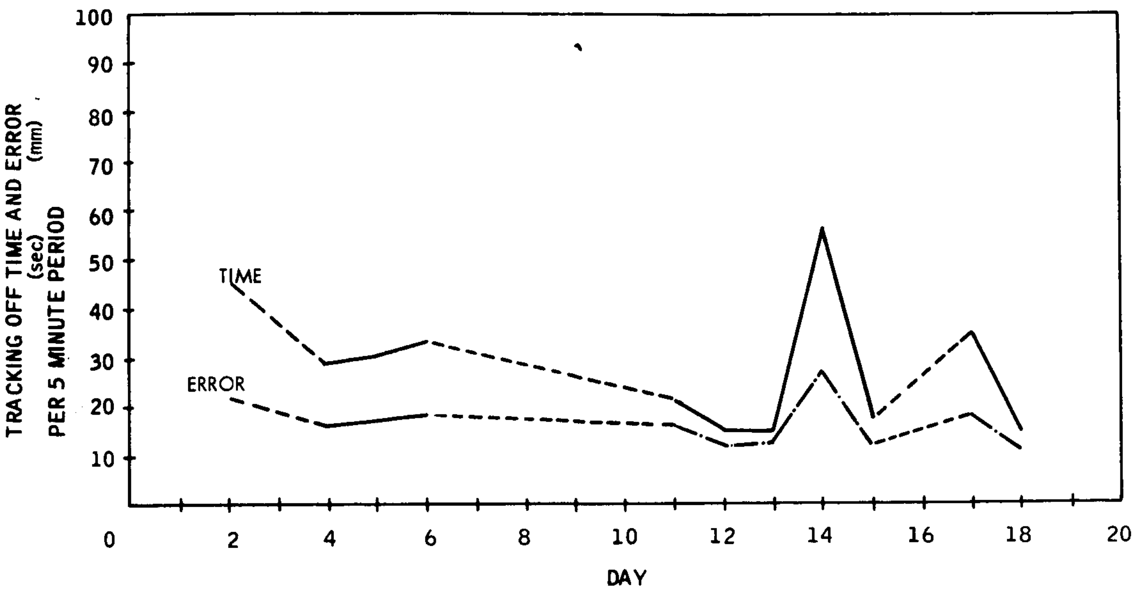


Figure I-1. Tracking Off-Time and Error - Both Operators, Speed 1

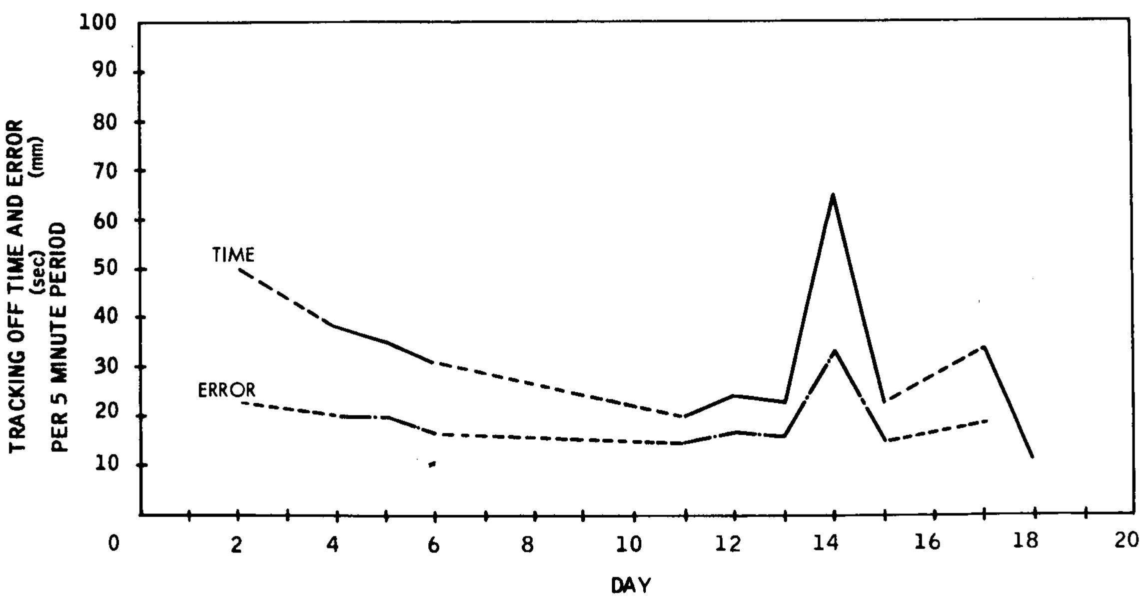


Figure I-2. Tracking Off-Time and Error - Both Operators, Speed 2

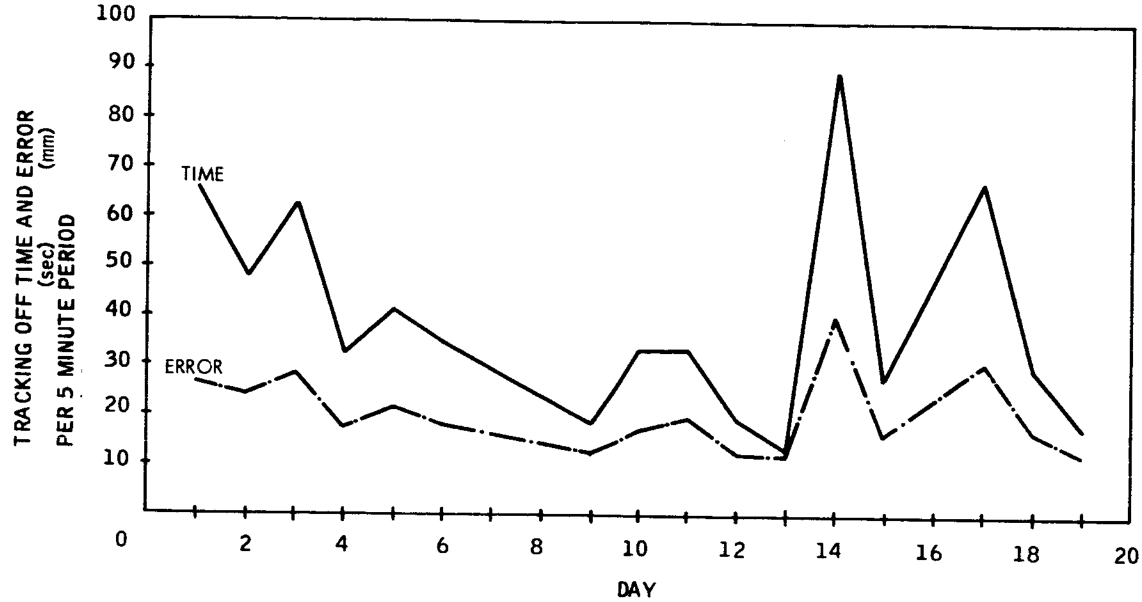


Figure I-3. Tracking Off-Time and Error - Operator 1, Speed 1

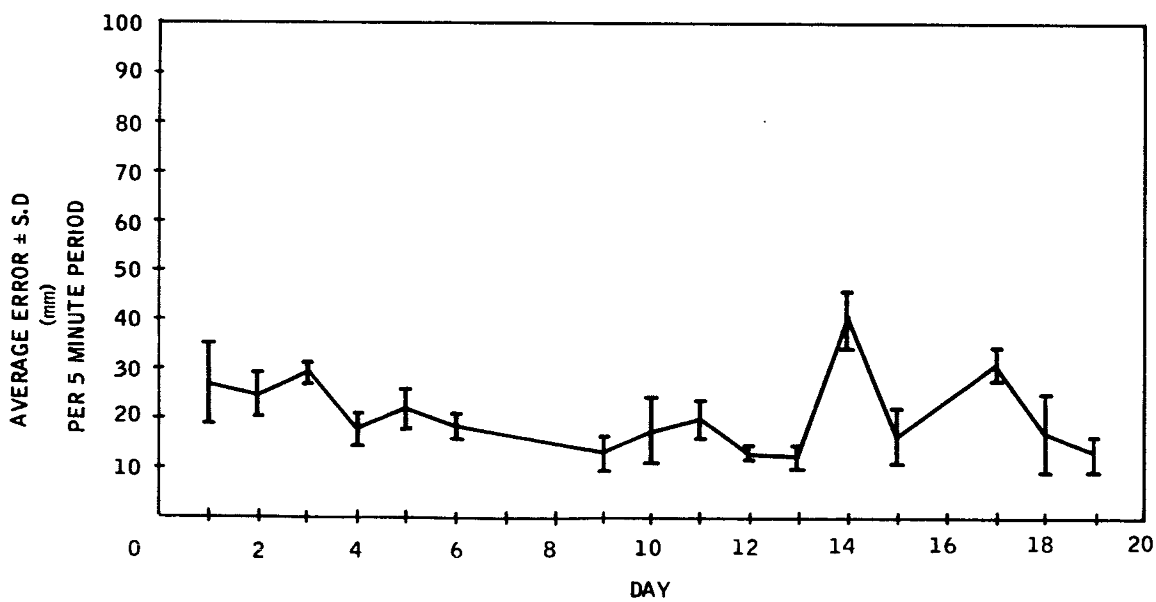


Figure I-4. Tracking Error - Operator 1, Speed 1

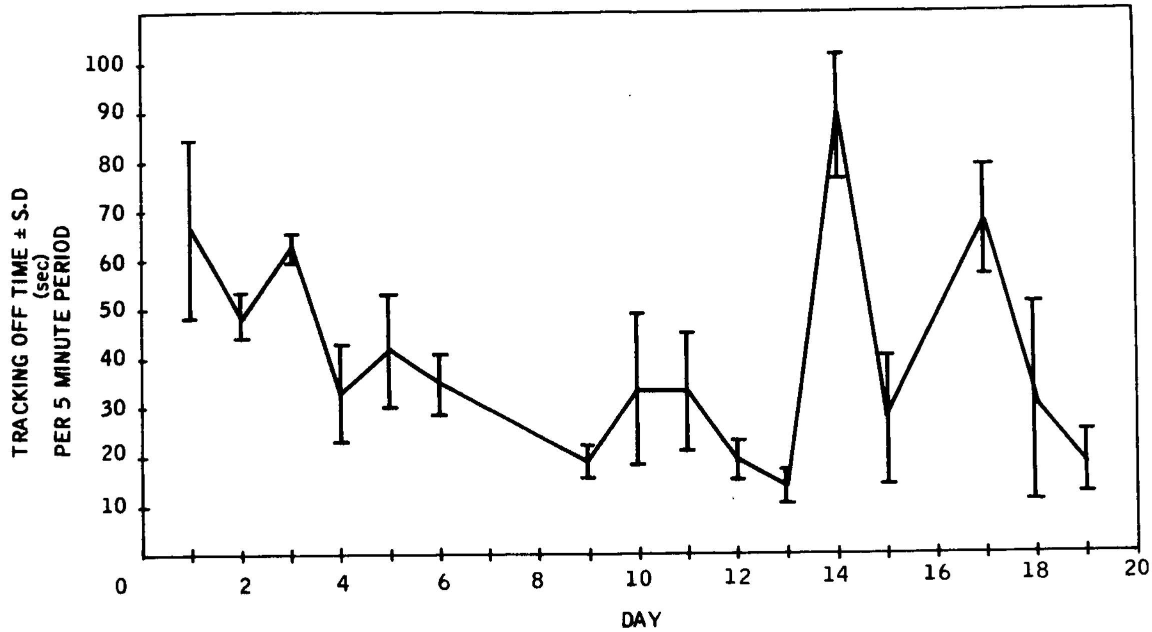


Figure I-5. Tracking Off-Time - Operator 1, Speed 1

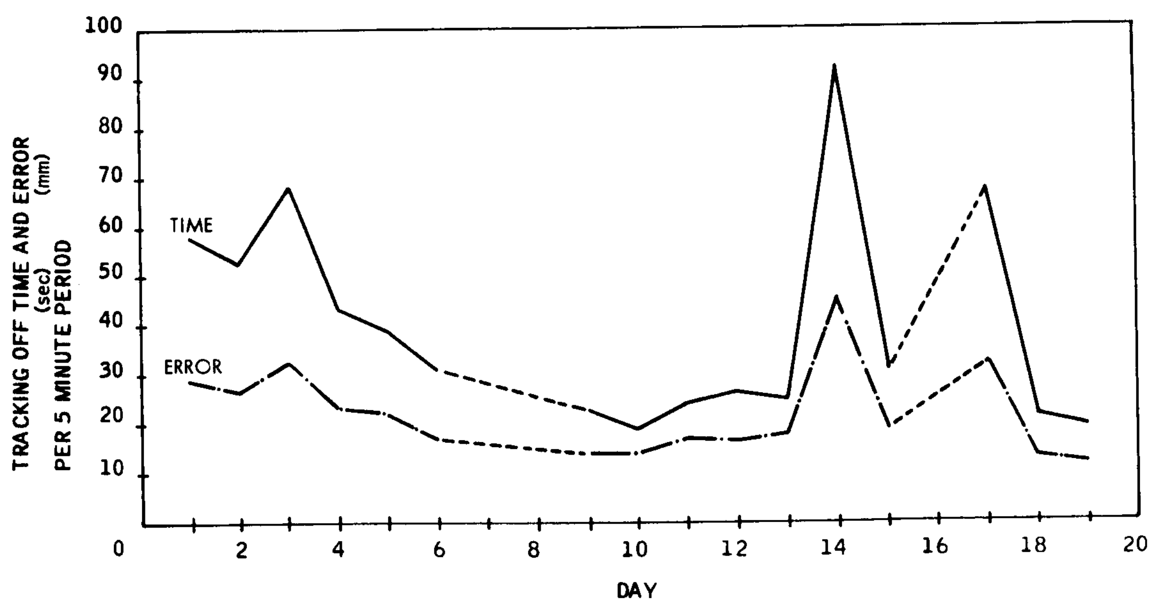


Figure I-6. Tracking Off-Time and Error - Operator 1, Speed 2

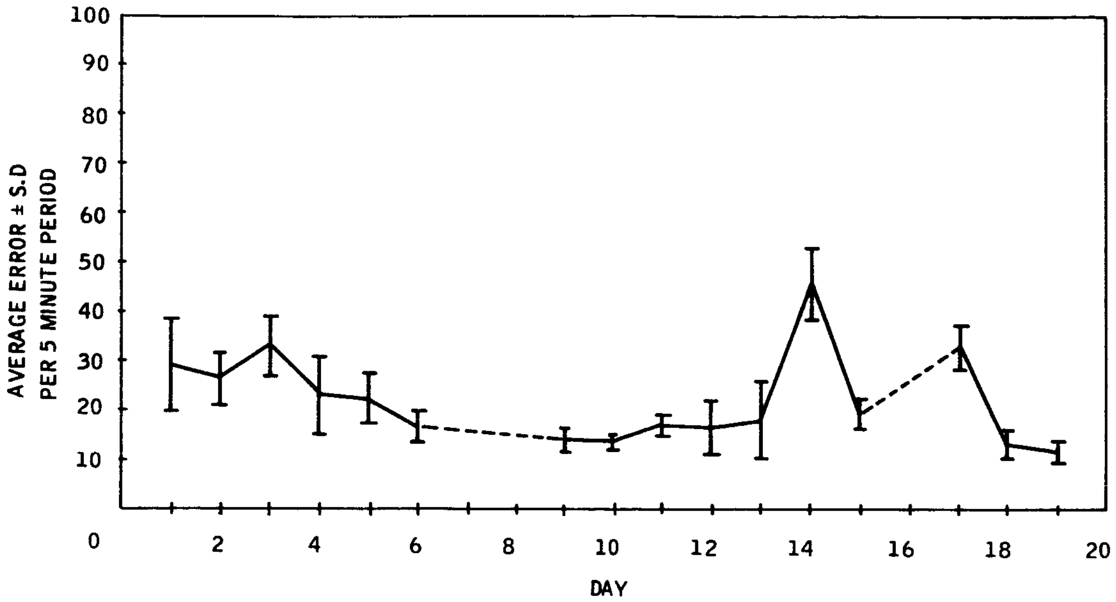


Figure I-7. Tracking Error - Operator 1, Speed 2

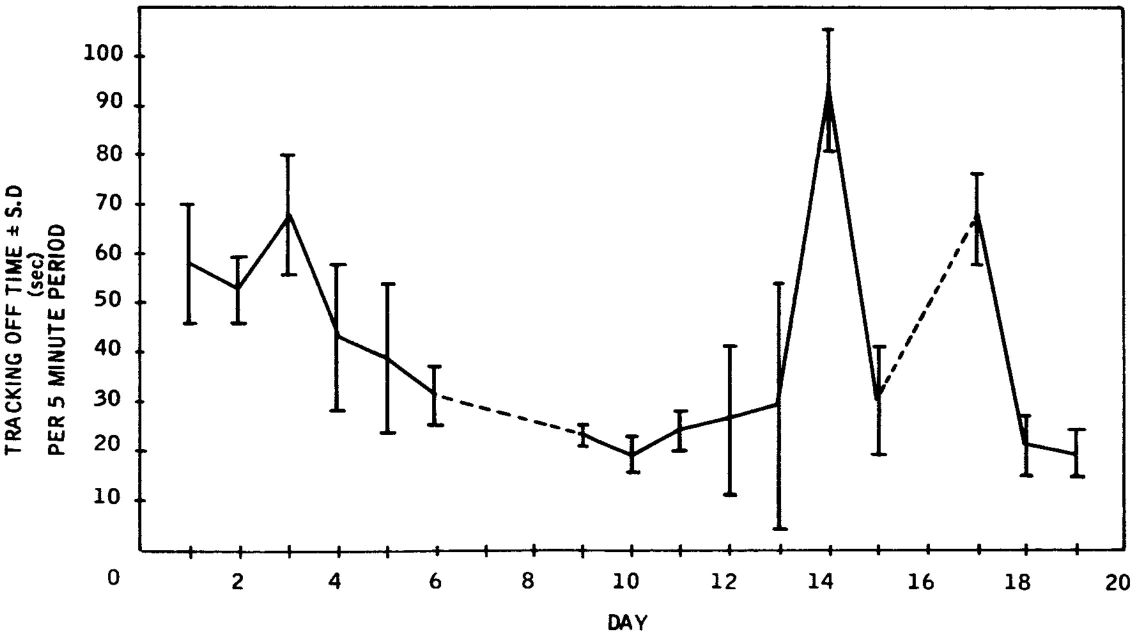


Figure I-8. Tracking Off-Time - Operator 1, Speed 2

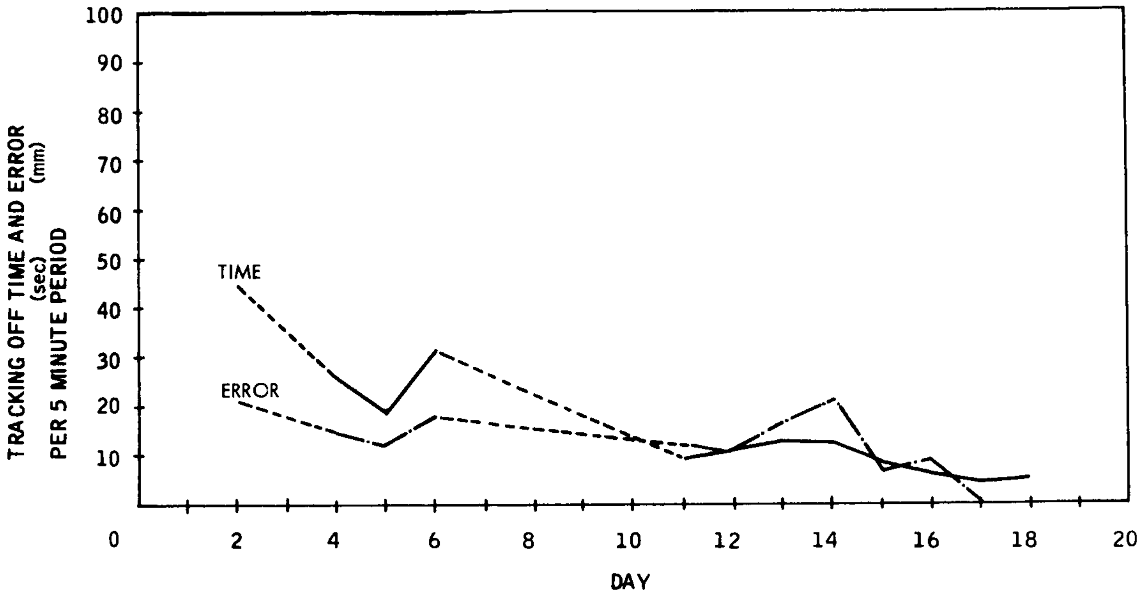


Figure I-9. Tracking Off-Time and Error - Operator 2, Speed 1

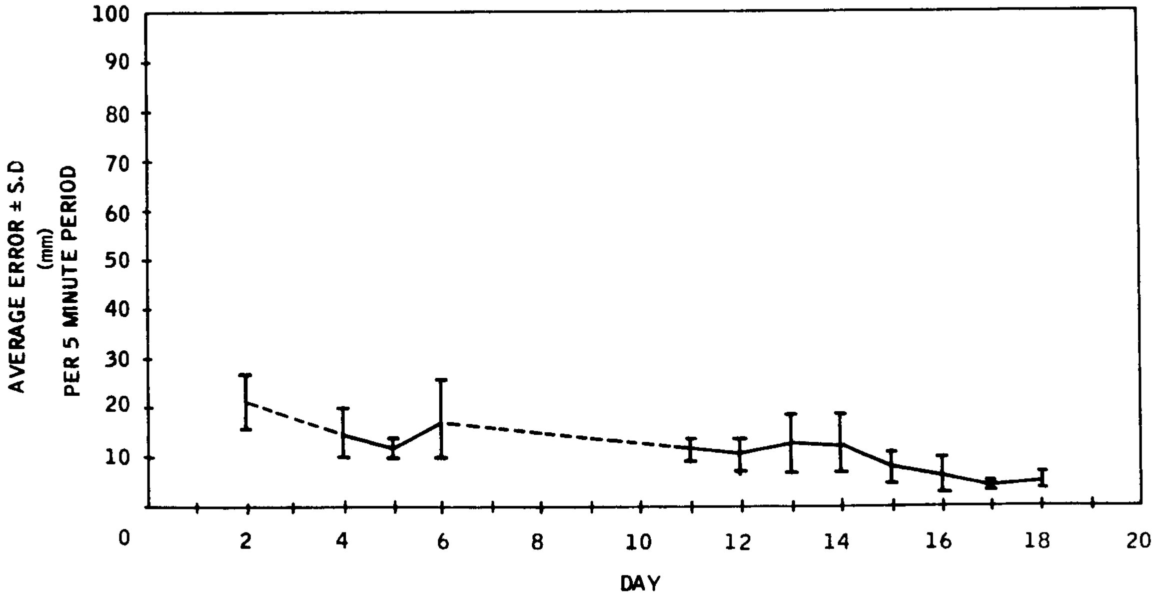


Figure I-10. Tracking Error - Operator 2, Speed 1

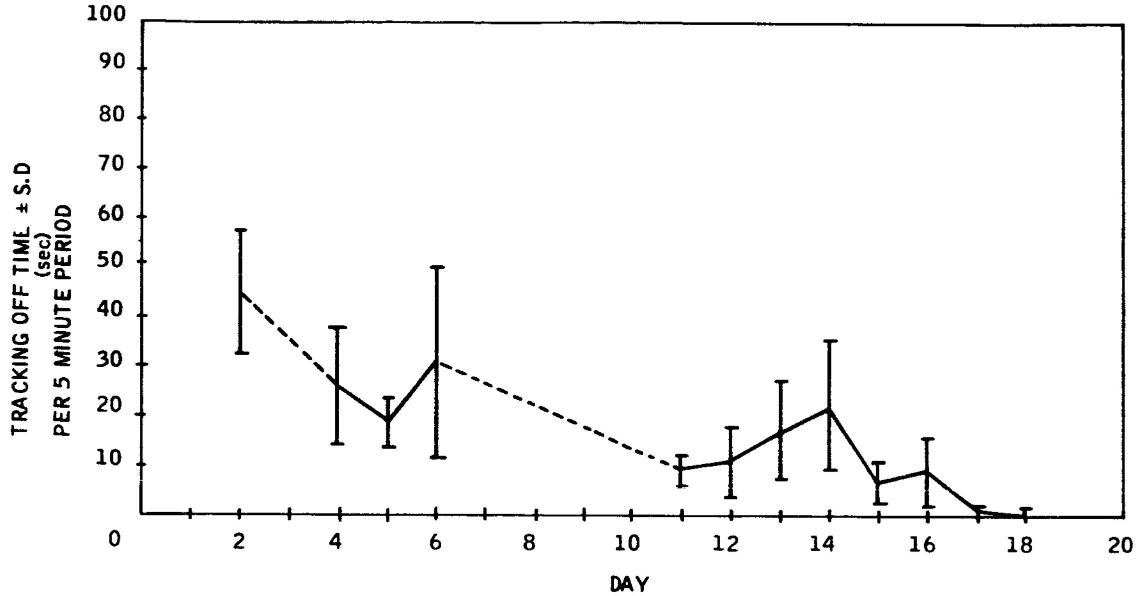


Figure I-11. Tracking Off-Time - Operator 2, Speed 1

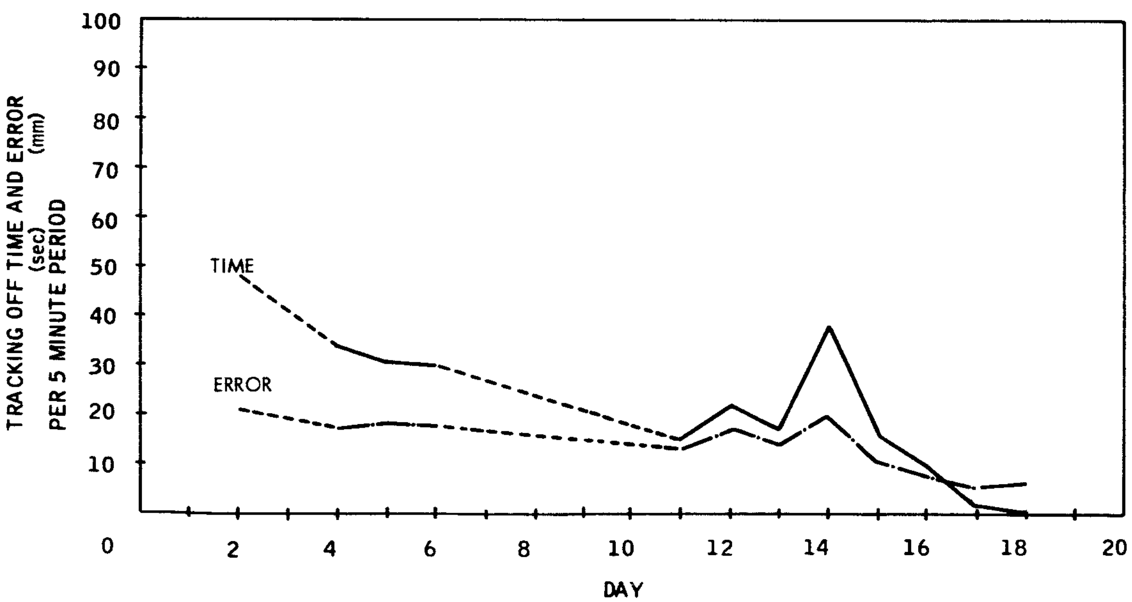


Figure I-12. Tracking Off-Time and Error - Operator 2, Speed 2

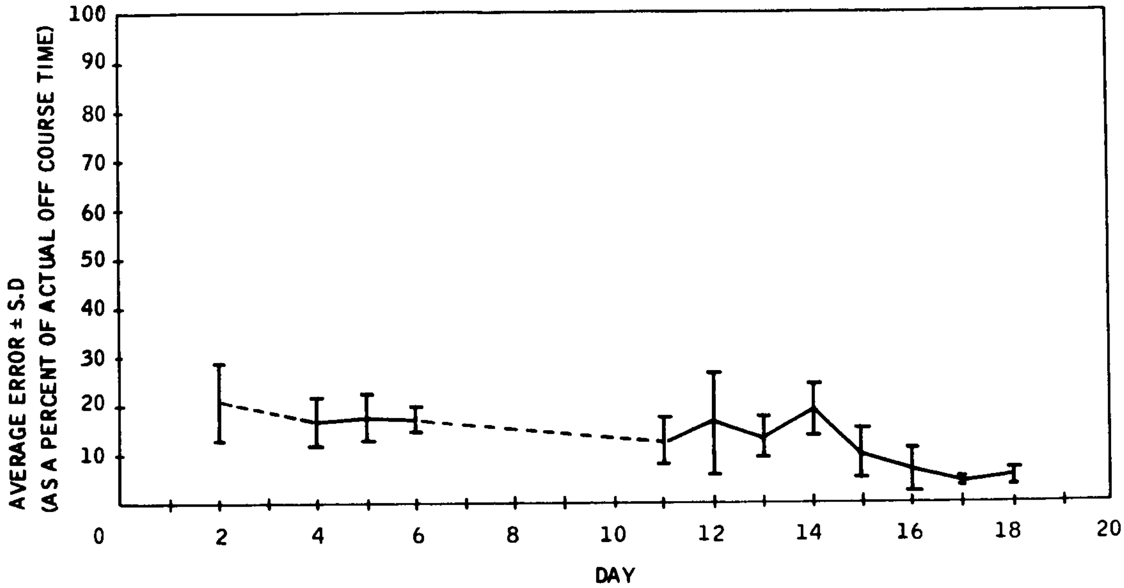


Figure I-13. Tracking Error - Operator 2, Speed 2

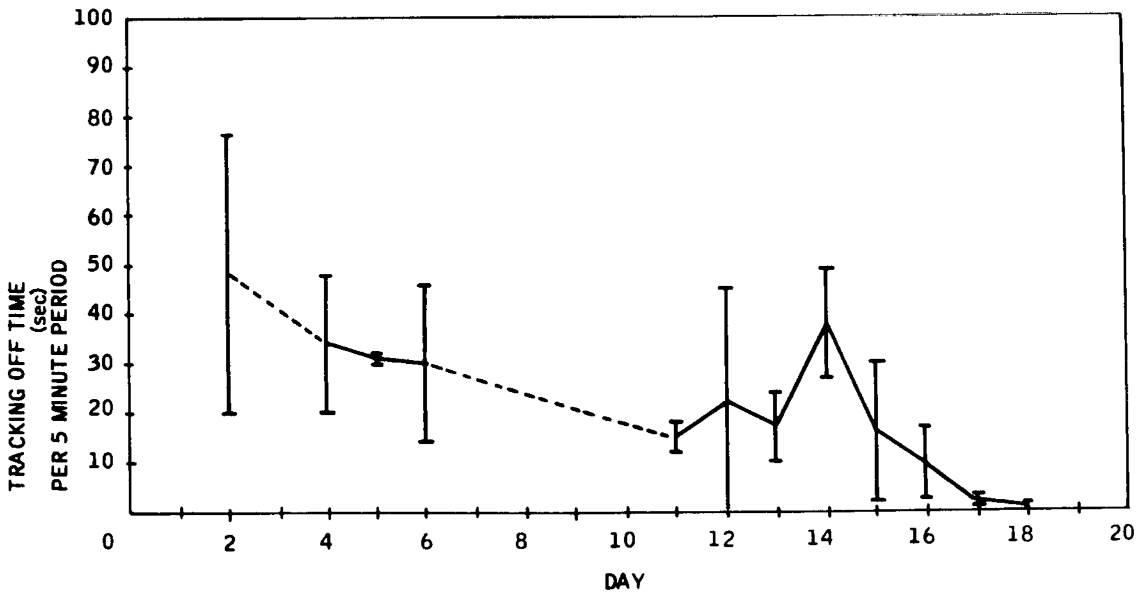


Figure I-14. Tracking Off-Time - Operator 2, Speed 2

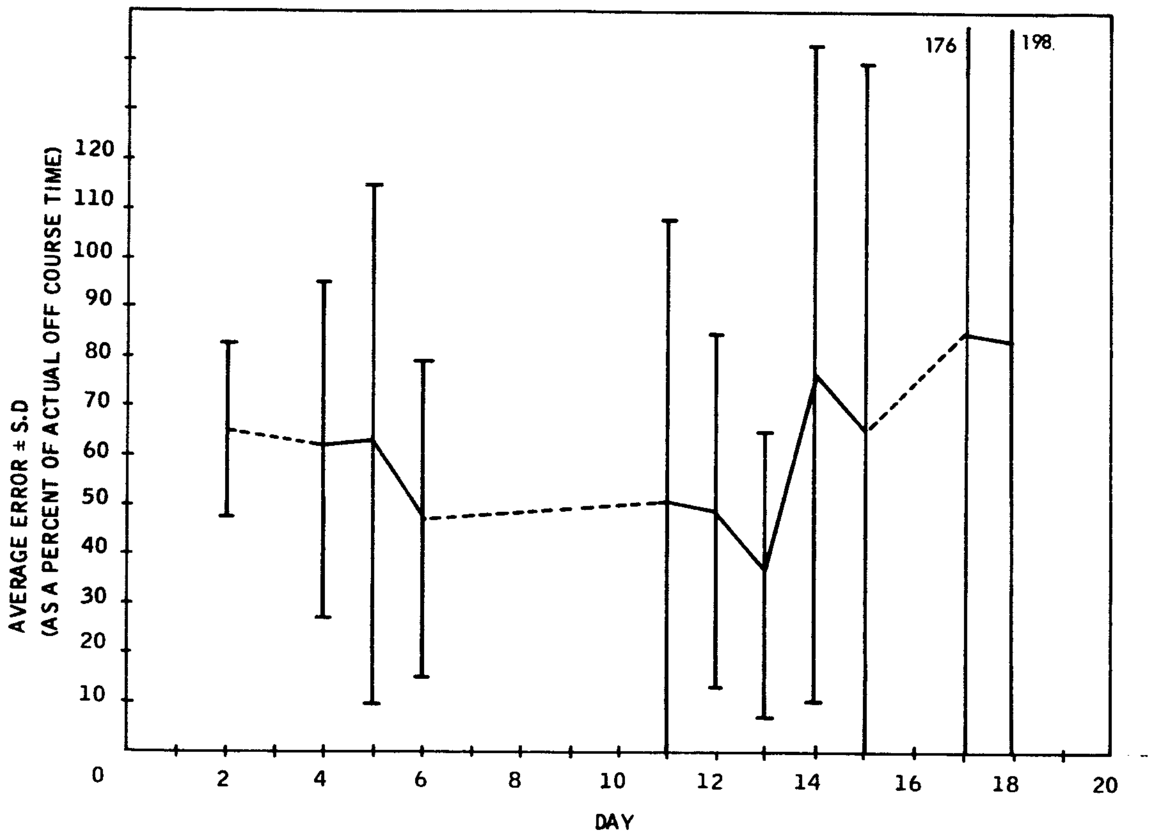


Figure I-15. Average Percent Monitoring Error - Both Operators, Speed 1

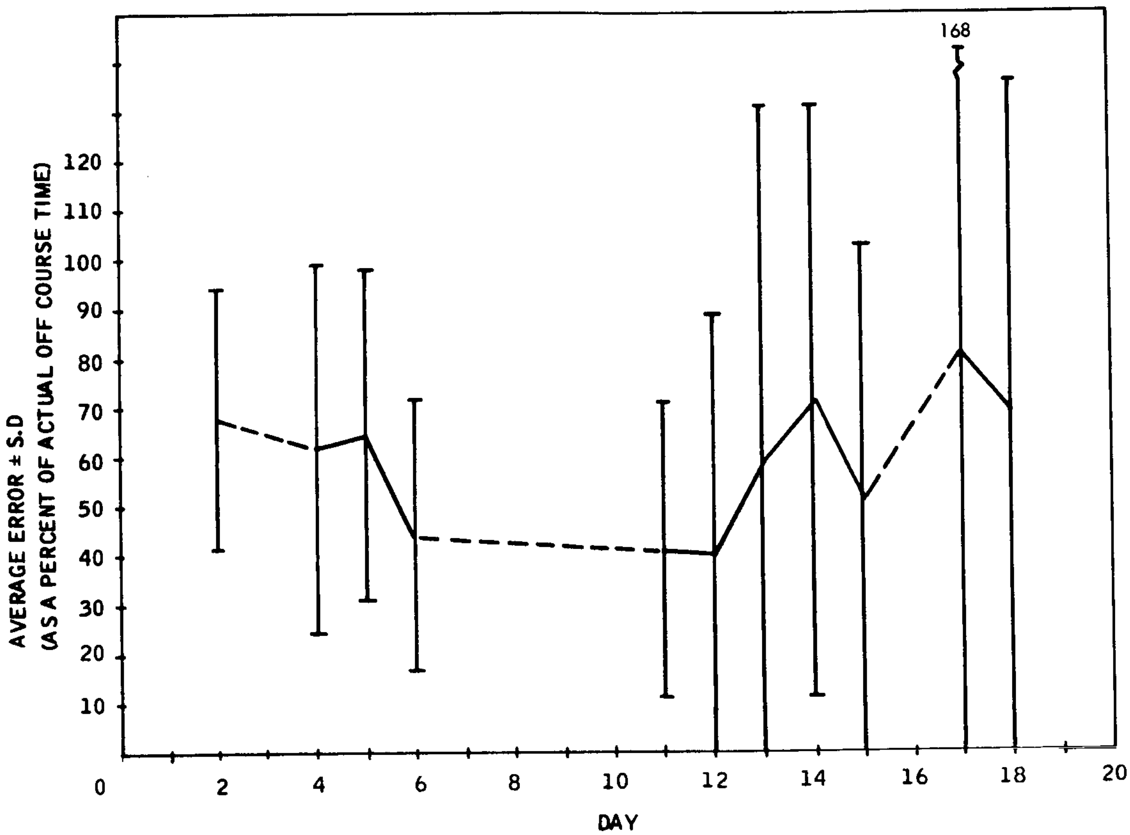


Figure I-16. Average Percent Monitoring Error - Both Operators, Speed 2

Op. 2	Date 2/20	Op. 1	Op. 2	Date 2/21	Op. 1	Op. 2	Date 2/22	Op. 1	Op. 2	Date 2/23	Op. 1	Op. 2	Date 2/24	Op. 1	Op. 2	Date 2/25	Op. 1
				Beds			Beds			Beds			Beds			Beds	
				Electrode C/O			Electrode C/O			Electrode C/O			Electrode C/O			Electrode C/O	
				Personal Hygiene			Personal Hygiene			Personal Hygiene			Personal Hygiene			Personal Hygiene	
				Meal 1			Meal 1			Meal 1			Meal 1			Meal 1	
			Suit C/O		Sci. Tasks	Suit C/O		Sci. Tasks	Suit C/O		Sci. Tasks	Suit C/O		Sci. Tasks	Suit C/O		Sci. Tasks
			Navigate		Chart		Don Suit			Scientific Tasks			Don Suit			Don Suit	
			Drive		Monitor	Inside		EVA	Drive		Monitor	Inside		EVA	EVA		Inside
				Meal 2			Doff Suit		Chart		Navigate		Doff Suit			Doff Suit	
				Don Suit			Meal 2			Meal 2		Monitor		Drive	Monitor		Drive
			EVA		Inside		Scientific Tasks		Monitor		Drive	Navigate		Chart	Chart		Navigate
				Doff Suit			Don Suit		Navigate		Chart		Meal 2			Meal 2	
			Chart		Navigate	Emergency		Inside		72 hr Report		Sci. Tasks		Suit C/O	Sci. Task		Suit C/O
			Monitor		Drive		Doff Suit		Drive		Monitor		Scientific Tasks			Scientific Tasks	
			Navigate		Chart				Chart		Navigate		Don Suit			Don Suit	
							Meal 3			72 hr Report		Inside		EVA	Inside		EVA
				Meal 3		Monitor		Drive		Meal 3			Doff Suit			Doff Suit	
				Scientific Tasks		Navigate		Chart	Monitor		Drive		Meal 3			Meal 3	
												Monitor		Drive	Drive		Monitor
Navigate		Chart					Scientific Tasks		Navigate		Chart	Navigate		Chart	Navigate		Chart
	MMPI		Monitor		Drive					Scientific Tasks			Scientific Tasks			Scientific Tasks	
	Meal 3		Navigate		Chart		Buffer Period			Buffer Period							
													Buffer Period				
Drive		Monitor	Sci. Task		Meal 4		Meal 4			Meal 4			Meal 4			Buffer Period	
Navigate		Chart		Meal 4			Scientific Tasks			Scientific Tasks			Scientific Tasks			Meal 4	
	Meal 4			Scientific Tasks												Maintenance	
	Remove Electrodes			Remove Electrodes			Remove Electrodes			Remove Electrodes			Remove Electrodes			Remove Electrodes	
	Personal Hygiene			Personal Hygiene			Personal Hygiene			Personal Hygiene			Personal Hygiene			Personal Hygiene	
	Beds			Beds			Beds			Beds			Beds			Beds	

Figure I-17. Detailed Evolution of Activity Sequences throughout the LUNEX II Simulation

Op. 2	Date 2/26	Op. 1
	Beds	
	Electrode C/O	
	Personal Hygiene	
	Meal 1	
Sci. Tasks		Suit C/O
	Don Suit	
Inside		EVA
	Doff Suit	
	Meal 2	
	Rest Period	
	Scientific Tasks	
	Don Suit	
EVA		Inside
	Doff Suit	
	Meal 3	
	Scientific Tasks	
	Maintenance	
	Meal 4	
	Remove Electrodes	
	Personal Hygiene	
	Beds	

Op. 2	Date 2/27	Op. 1
	Beds	
	Electrode C/O	
	Personal Hygiene	
	Meal 1	
Suit C/O		Sci. Tasks
	Don Suit	
EVA		Inside
	Doff Suit	
	Scientific Tasks	
	Meal 2	
	Rest Period	
	Scientific Tasks	
	Meal 3	
	Opinion Forms	
	Scientific Tasks	
	Buffer Period	
	Meal 4	
	Scientific Tasks	
	Remove Electrodes	
	Personal Hygiene	
	Beds	

Op. 2	Date 2/28	Op. 1
	Beds	
	Electrode C/O	
	Personal Hygiene	
	Meal 1	
	Scientific Tasks	
	7-day Report	
Sci. Tasks		Suit C/O
	Meal 2	
	Rest Period	
Suit C/O		Sci. Tasks
	Scientific Tasks	
	Don Suit	
Inside		EVA
	Crew Exchange	
EVA		Inside
	Doff Suit	
	Meal 3	
Drive		Monitor
Chart		Navigate
	Scientific Tasks	
	Buffer Period	
	Meal 4	
	Scientific Tasks	
	Remove Electrodes	
	Personal Hygiene	
	Beds	

Op. 2	Date 3/1	Op. 1
	Beds	
	Electrode C/O	
	Personal Hygiene	
	Meal 1	
	Scientific Tasks	
	Suit Checkout	
Drive		Monitor
Chart		Navigate
	Don Suit	
EVA		Inside
	Crew Exchange	
Inside		EVA
	Doff Suit	
	Meal 2	
	Rest Period	
	Scientific Tasks	
Monitor		Drive
	Meal 3	
Navigate		Chart
	Scientific Tasks	
	Buffer Period	
	Meal 4	
	Remove Electrodes	
	Personal Hygiene	
	Beds	

Op. 2	Dates 3/2 - 3/3	Op. 1
	Beds	
	Electrode C/O	
	Personal Hygiene	
	Meal 1	
Drive		Monitor
Chart		Navigate
	Suit Checkout	
	Don Suit	
EVA		Inside
	Crew Exchange	
Inside		EVA
	Doff Suit	
	Meal 2	
	Rest Period	
	Scientific Tasks	
Monitor		Drive
	Meal 3	
Navigate		Chart
	Scientific Tasks	
	Buffer Period	
	Meal 4	
	Remove Electrodes	
	Personal Hygiene	
	Beds	

Op. 2	Dates 3/4 - 3/18	Op. 1
	Beds	
	Electrode C/O	
	Meal 1	
	Personal Hygiene	
Drive		Monitor
Chart		Navigate
	Don Suit	
EVA		Inside
	Crew Exchange	
Inside		EVA
	Doff Suit	
	Meal 2	
	Rest Period	
	Scientific Tasks	
Sci. Tasks		Suit C/O
Suit C/O		Sci. Task
Monitor		Drive
Navigate		Chart
	Meal 3	
	Scientific Tasks	
	Buffer Period	
	Maintenance	
	Meal 4	
	Reports and Personal Activity	
	Personal Hygiene	
	Remove Electrodes	
	Beds	

Figure I-17. Detailed Evolution of Activity Sequences throughout the LUNEX II Simulation (continued)

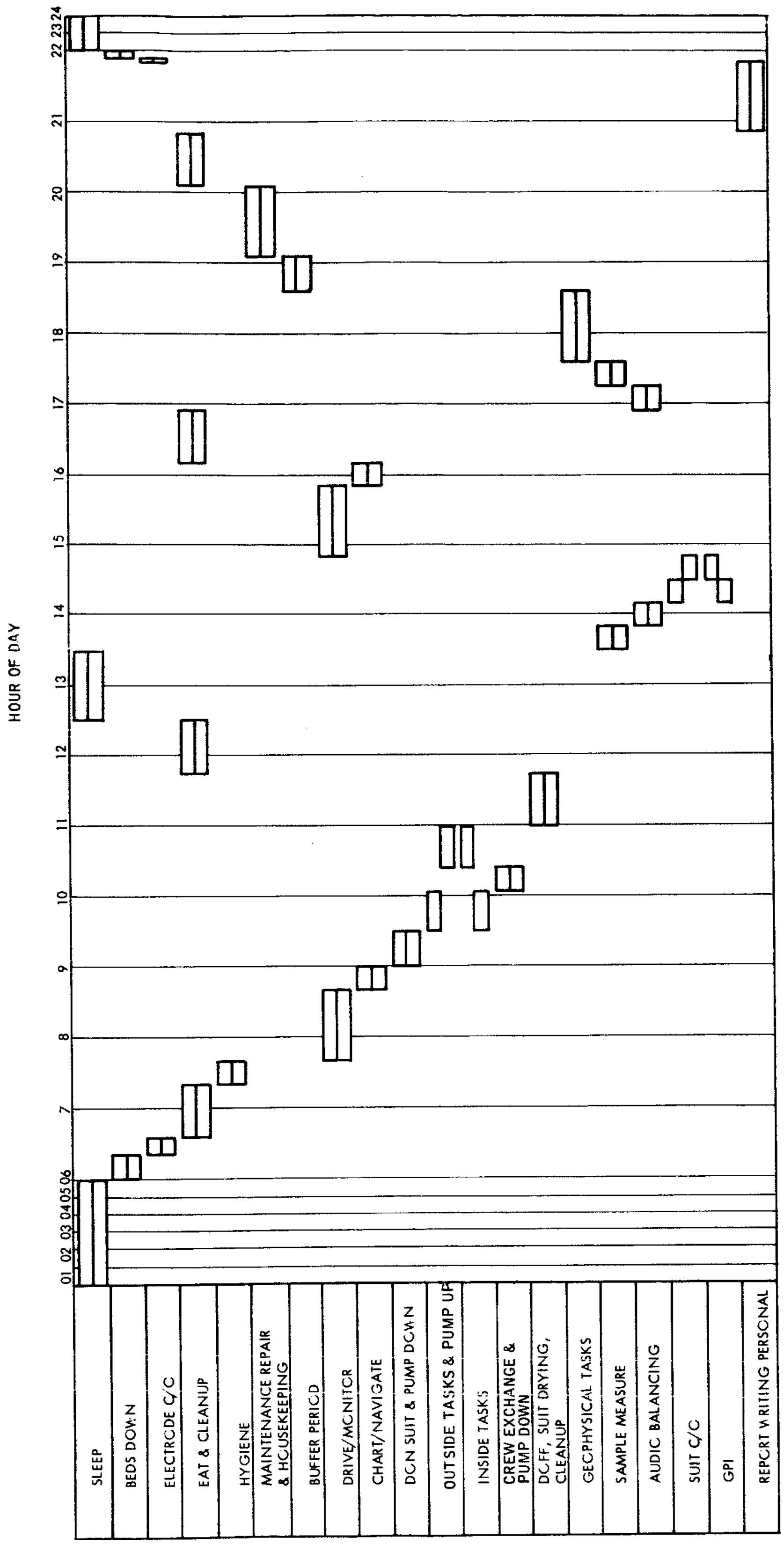


Figure I-18. Block Diagram of LUNEX II Time Line

Table. I-1. Skill Retention/Pattern Recognition Task, Response Times and Errors - Operator 1

Pattern*	Time to Make the Correct Response (sec)																				Averages
DAY	2	2	3	4	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
1 X	3.02	1.82		2.90	2.75	1.65	1.77				1.34	3.83	1.72	1.60		1.84		1.24	1.24		2.05
1 Y		2.90		1.90	3.86	1.60					1.33	3.44	1.43	1.55				1.58	1.07		2.09
4 X	5	3.30		2.60	2.11	1.91	2.05				3.62	3.65	2.00	2.28				1.71	2.24		2.70
4 Y	6	6.52		2.80	2.90	2.64	3.83				3.44	2.16	2.64	1.91				2.27	2.22		3.28
7 X	7	2.48		1.87	1.74	2.43	1.78				2.10	7.50	1.76	1.69		1.37		2.48	1.55		2.74
7 Y	3.5	4.64		2.46	1.91	1.80	2.06				1.70	8.06	1.92	1.81		1.89		1.97	1.53		2.71
2 X	1.2					1.72													1.56		1.49
2 Y				4.37							3.85	3.46		2.79					2.10		3.32
5 X						2.63										4.60			1.89		3.04
5 Y		1.80					1.64									3.70		3.20	1.82		4.32
3 X		4.90									2.20								1.89		3.00
3 Y																3.22			2.08		2.64
6 X	>4																		3.76		3.88
6 Y																			3.73		3.73
Averages	4.25	3.52		2.70	2.53	2.04	2.17				2.48	4.60	1.91	1.96		2.77		2.06	2.04		

Pattern*	Errors																			
DAY	2	2	3	4	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1 X	0	0		1	0	0	0				0	5	0	0		0		0	0	
1 Y		0		0	1	0					0	8	0	0				0	0	
4 X	2	1		0	0	0	0				2	8	0	1				1	0	
4 Y	1	1		0	0	0	1				1	0	0	0				0	0	
7 X	1	0		0	0	0	0				0	25	0	0		0		0	0	
7 Y	1	3		0	0	0	0				1	5	0	0		0		0	0	
2 X	0					0													0	
2 Y				2							2	3		1					0	
5 X						0										0			0	
5 Y		0					0									1		1	1	
3 X		1																	0	
3 Y																0			1	
6 X	1																		5	
6 Y																			5	
Totals	6	6		3	1	0	1				6	54	0	2		1		2	12	

* See Figure 36.

Table I-2. Skill Retention/Pattern Recognition Task, Response Times and Errors - Operator 2

Pattern*	Time to Make the Correct Response (sec)																				Averages
7 X		1.60	1.34	1.20		1.66	1.43			1.42	1.68		2.15	1.59	2.28	1.52		1.58		1.25	1.59
7 Y		0.64	1.64	1.39	1.48	0.66	1.32			5.73			1.27	1.66	1.61	1.65		1.48	1.61	1.37	1.65
34 X		3.10	1.70	1.20	1.30		1.12			1.26	1.42	1.10	1.30	1.27	1.38	1.16		1.29	1.43	1.34	1.42
34 Y		6.64	2.10	1.42	1.28		1.88			1.27	1.64			1.70				1.28	1.04	1.04	1.94
57 X		4.37	3.14	2.48	1.80		1.80			2.61	1.69		1.48	1.30				3.14	1.67	1.72	2.26
57 Y		1.32	2.95	2.29			3.50							1.64				2.34	2.44	2.60	2.38
42 X		2.44				1.60									1.79	1.64		1.91		1.92	1.88
42 Y				2.68		6.35				2.64				2.29	1.40	1.37				1.70	2.63
25 X										1.92						2.72				1.54	1.70
25 Y			1.87								2.46								10+	1.59	3.99
63 X			4.94																	4.17	4.51
63 Y																				1.90	1.90
16 X		3.58				3.20									1.84	1.74				1.66	2.41
16 Y						2.90	1.26								2.95	1.67				2.43	2.34
Averages		2.96	2.46	1.81	1.46	2.72	1.84			2.41	1.78	1.10	1.35	1.63	1.89	1.56		1.86	3.03	1.88	
DAY	2	2	3	4	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	

Pattern*	Errors																			
71 X		1	0	0		0	0			0	0		0	0	0	0		0		0
71 Y		0	0	0	1	0	1			0			0	0	0	0		0	0	0
34 X		0	0	0	0	0	0			0	0	0	0	0	0	0		0	0	0
34 Y		2	0	0	0		0			0	0			0				1	0	0
57 X		1	1	0	0		0			0	0		0	0				2	0	1
57 Y		1	0	1			1							0				2	1	1
42 X		0				0									0	0		0		0
42 Y				1		2				0				0	0	0				0
25 X										0						0				0
25 Y			0								0								12	0
63 X			0																	1
63 Y																				0
16 X		0				0									0	0				0
16 Y						0	0								0	0				1
Totals		5	1	2	1	2	2			0	0	0	0	0	0	0		5	13	4

* See Figure 36.

APPENDIX II
RESULTS OF MID-SIMULATION MEDICAL EXAMINATION

APPENDIX II
RESULTS OF MID-SIMULATION MEDICAL EXAMINATION

Both subjects were given physical examinations after 10 days in the simulator. The examinations were administered by Dr. Milton Alter of the Department of Neurology, University of Minnesota. His report follows:

MICHAEL J. VACCARO (OPERATOR 1)

The subject is a 38-year-old male. He has no specific complaints regarding his physical condition. He pointed out that he tended to bump his head frequently on the low ceiling after a day or so of being in the chamber. He complained about the visual task, reporting that it made his eyes tear and that he awoke in the morning with matter in the eyes. The irritation of the eyes has decreased in the last day or so. He no longer wears his contact lenses; pointed out that he is nearsighted and does not need them in the chamber.

Past History

Includes allergies for which he takes antihistamines in the summertime. The allergies are characterized by irritation of the eyes and sneezing (he has sneezed occasionally in the chamber). For the first few days he complained of sore throat, a residual of an upper respiratory infection which he had for about two weeks before the simulation was started. He had an appendectomy in 1950.

Review of Systems

Subject denies headaches; he is sleeping well and feels rested. He has had no double vision nor do his eyes tire unduly except while performing the visual driving task. His hearing is good, sense of smell is normal. He perceives odor of special diet and bowel movements. He no longer has throat discomfort on awakening, although his nose tends to be a bit stuffy. There is no shortness of breath, chest pain or coughing. He experienced no palpitation or skipped beats. His abdomen does not feel bloated, and his bowel movements have been regular, about once a day. He is "always hungry" and looks forward to each meal. Urination has been normal. He has entered a "contest" with Operator 2 to see who can put out more urine at one time. He has experienced an occasional erection, which is not unusual for him. He denies any stiffness of the joints and has no muscle tenderness.

On physical examination blood pressure was 112/78 right arm, sitting; 114/74 left arm, sitting. The pulse was 68 and regular. He appeared alert and answered questions with obvious interest and sincerity. He appeared to be trying to do his best. There were no bruises about the head, or the limbs, or on the trunk. The condition of the skin was good and there was no displeasing odor. There was some conjunctival infection, about equal in both eyes; there were several dilated vessels over the sclera. Olfaction was normal; funduscopy showed no abnormality of the retina. Extra ocular movements were full. The pupils measured about 3 mm and were equal. They reacted to light directly and consensually. They also reacted on accommodation. The subject read the smallest type on the standard card. Facial sensation was normal. The jaw strength was normal. The face moved symmetrically. Taste was normal; hearing was intact. The palate elevated in the midline. The neck muscles were strong. The tongue protruded centrally.

Motor power was excellent and muscle tone was normal.

Deep tendon reflexes were 1+ bilaterally and no abnormal reflexes were elicited. Response to pin prick and touch were normal. Vibratory threshold was normal for the age. Position sense was intact. He identified fingers correctly when placed in the palm but consistently misnamed a dime as a penny on the left hand. Identical objects were perceived as being heavier in the left hand.

Coordination was normal on finger to nose and heel to shin test. Rapid alternating movements were normal. Standing with feet together and eyes closed produced no swaying. Ears, nose, throat, chest, heart and abdomen were normal.

Impression

This subject is in good physical condition and appears psychologically capable of continuing the experiment. He is, in fact, well motivated to do so. The only abnormality of note was the conjunctival infection which may be related to exposure to ultraviolet light. The subject has a history of allergies which also manifests by eye stimulus. The possibility of ultraviolet exposure should be investigated and if present, eliminated.

HAYDON GRUBBS (OPERATOR 2)

The subject is 34 years old, male. He has no specific physical complaints. He was troubled by the small size of the sleeping arrangement until he found a position which allowed him to stretch his legs. There was some stiffness of the neck initially, brought on by the need to keep the head flexed almost continually in the small chamber. He described dissatisfaction with the visual driving task, noting specifically that it was difficult to follow the broken vertical line. He suggested that a solid vertical line would ease the task considerably. There was also some eye discomfort when performing the visual driving task.

Past History

Left mastoidectomy as a child; fractured right clavicle in the teens.

Review of Systems

He denies headaches; his vision is good, there has been no matter in the eyes. His hearing, smell and taste are normal. He had less difficulty than Operator 1 in determining between scotch and bourbon. There is no swallowing difficulty or soreness of the tongue. He has no chest pain, shortness of breath, no palpitation or skipped heartbeat. He feels his response to activity on the treadmill is better now than before the experiment was started. He is always hungry. One day there was excessive belching and flatus, probably on the 7th day. The onion in the diet may have been responsible, but he enjoyed the onion. Urination has been normal in frequency and amount. He has had no erections. He denies joint and muscle discomfort.

He takes no medication routinely.

On physical examination the blood pressure was 106/68, right arm and 94/74 left arm. The pulse was regular at 64. He was well motivated, alert and responded quickly and appropriately to questions. He appeared rather tired and had puffiness below the eyes. The eyes were only slightly infected, much less so than in Operator 1. The ear canals were plugged with wax; the throat had no redness; there was no adenopathy in the neck. The chest was clear, the heart was regular, the abdomen was soft. Neurological examination showed intact olfaction, the extra ocular movements were full but there was some nystagmus in the horizontal plane on lateral gaze. Pupils were 3 mm bilaterally and reacted well to light directly and consensually. They also reacted on accommodation. Visual fields were full by confrontation and funduscopy was normal. Facial sensation was normal, jaw strength was good, face moved symmetrically. Taste was intact for salt and sugar although the subject had difficulty recognizing the taste stimulus on the left side for the first two trials. Hearing is intact. The palate elevated in the midline, the neck muscles were strong, the tongue protruded centrally.

Motor power was excellent, tone was normal. Tendon reflexes were brisk but no pathological reflexes were elicited.

Coordination was intact on finger to nose and heel to shin test; rapid alternating movements were well performed. The subject stood well with feet together and eyes closed even when feet were in tandem position.

Touch, position, pin prick and vibration were intact. Sterilognosis was normal.

Temperature was well perceived. The subject identified coins placed in the hands and had no difficulty in weight discrimination.

There was a small, triangular bruise above the right knee. Chest, heart, abdomen were normal. Ears had usual amount of wax. Nose and throat were normal.

Impression

The subject is in good physical and psychological condition and appears to be capable of continuing the experiment.

APPENDIX III

COMPUTER TREATMENT OF PRINCIPAL TASK DATA

APPENDIX III

COMPUTER TREATMENT OF PRINCIPAL TASK DATA

Five programs were written to generate means, standard deviations, ΣX, ΣX^2, N for any number of experimental conditions, if coded numerically (cond 1, 2, ... n), for the following situations:

1. For a particular period of time (e. g. , a day), for N trials (unspecified)
   - For any subject
   - For pooled data from two subjects only
2. For any subject over an unspecified number of subperiods of time
3. For two subjects' data pooled over subperiods of time (unspecified)

The differences in the five programs result mainly from the number and kinds of measurements obtained from the experimental situation, e. g. , raw scores as opposed to differences between raw scores, the kinds of calculations to be suppressed for reason of insufficient data points, and the variable control gained from sorting on different columns for different kinds of tasks.

The programs could be combined into a very general one, dimensions could be extended, and instructions added to handle pooled data for any number of subjects, the size being limited by available memory.

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PURPOSE

The five programs and their purposes are as follows:

- UASTX1 (Drive Task) - Computes ΣX, ΣX^2, N, Mean, Standard deviation for task time, four physiological measures, $\int |e| dt$, and time off course for two or more driving speeds for a particular time period (a day) for N individual subjects and for two pooled subjects. These calculations may be arrived at as a subgroup under any number of experimental conditions (1, 2, ... n) if so coded. The standard deviation for task time was suppressed since the time interval was constant.

- UASTX2 (Monitor Task) - Computes the same elements as UASTX1 for task time and physiological measures, but for the differences between two measurements (time off course and monitored time off course). Standard deviation of task time was again suppressed for the constant task time interval.

- UASTX4 (Navigation Task) - Computes the five items mentioned above for the differences between angles θE_1, θS_1, and angles θE_2, θS_2; for the four physiological measures; and the task time for n periods for a particular day for N individual subjects and for two pooled subjects for each period; and over all periods for the day. The standard deviation for task time is suppressed since the number of data points was so few.

- UASTX5 (Audio Frequency Balancing Task) - Computes the same five elements, four physiological factors, and differences between two measured frequencies for a particular period of unit time (a day) for N individual subjects and for two subjects (data pooled); also, for each subject and two pooled subjects over all periods of time.

- UASTX6 (Sample Measurement) - Same as above except for formats and the suppression of standard deviation of task time. Time was recorded only once every six trials resulting in too few data points.

CODING INFORMATION

DSSX = Sum X
DSSQ = Sum of squares (X^2)
TRL = Number of trials (1 per card)
1st total level
AVP = Mean = DSSX/TRL
SDP = Stand deviation = SQRT (TRL*DSSQ-DSSX**2)/(TRL*TRL-1.0)
2nd total level
TTRL = TRIALS
TX = Sum X
TXQ = Sum X^2
AVS = Mean
SDS = Standard Deviation
1 and 2 = subject identification
AVT and SDT - special calculations for task time when time was not recorded for each trial

Grand Total

TPX = Sum X
TPQ = Sum X^2
TAV = Mean
TSD = Standard Deviation

Integer Controls

NP1 = number of periods or driving speed control for Subject 1

NP2 = number of periods or driving speed control for Subject 2

IP = sequential period identification

M = indicates level of totals to be taken

NEP = highest number of periods reached - controls totaling over periods total one day.

Arrays

(For UASTX1, UASTX2, UASTX4, All arrays showing a size 6 or X, 6 substitute 8.)

IFORM (10) identification data

TIMO(2) Time in minutes and seconds

RHR(4) physiological data - integer form

DSC(5) non-physiological data - integer form

DSC(5) non-physiological data - decimal form (actual dimensions vary from (2) to (5) depending on the program)

IFMT(10) Temporary storage of identification data

DSSX (6) first-level storage ΣX

DSSQ (6) second-level storage ΣX^2

STRX1(4, 6) second-level storage ΣX Subject 1

STRX2(4, 6) second-level storage ΣX Subject 2

STRQ1(4, 6) second-level storage ΣX^2 Subject 1

STRQ2(4, 6) second-level storage ΣX^2 Subject 2

STRL1(4) second-level storage Trials Subject 1

STRL2(4) second-level storage Trials Subject 2

TRL = number of trials first level

AVP1(4, 6) Mean computation first level

SDP1(4, 6) Standard deviation computation first level

TX1(6) Total ΣX for Subject 1 over all periods

TX2(6) Total ΣX^2 for Subject 2 over all periods

TQ1(6) Total ΣX^2 for Subject 1 over all periods

TQ2(6) Total ΣX^2 for Subject 2 over all periods

TPX12(6) Total ΣX for Subject 1 and Subject 2 over all periods

TPQ1, 2TPQ12(6) Total ΣX^2 for Subject 1 and Subject 2 over all periods

AVS1(6) Mean storage after calculation over all periods for Subject 1

AVS2(6) Mean storage after calculation over all periods for Subject 2

SDS1(6) Standard Deviation Storage after calculation over all periods for Subject 1

SDS2(6) Standard Deviation Storage after calculation over all periods for Subject 2

AVP12(6) Mean storage for Subject 1 and Subject 2 over all periods

SD12(6) Standard Deviation Storage for Subject 1 and Subject 2 over all periods

SX(12) Grand total ΣX and ΣX

TAV(6) Grand mean

TSD(6) Grand Standard Deviation

OPERATING INSTRUCTIONS

STOP - Normal STOP

Pause Mount - Work Tapes Units 16, 21, 22 (Logical Tapes 1, 2, 3)
Logical Tape 3 stores ΣX and ΣX^2 for each day.

16K 100 cards per minute

INPUT

Punched cards must be sorted in the following fashion

Task 1, 2 ; Task 4 5 6

Col 19 Speed → 3 Subj ← Col 17 period

3 Subj

↓

7.8 day

↓

9 Condition

↓

1, 2 task

Final Data card required for each program Col (1 and 2) 99

Units for input parameters are limited only by format statements

OUTPUT

Printed data varies according to format from program to program.

All time outputs are in seconds correct to 1/100th.

The following pages show the raw data format used and sample computer program listings.

TASK: MONITOR SUBJECT

TASK ID	S #	DATE	DAY	CON	TASK #	TIME	TRIAL #	TIME MIN SEC 1/100S	H.R. INIT	RR INT	H.R. MAX	RR MAX	TIME OFF COURSE	MONITORED TIME OFF COURSE	Δt OFF-MON
(1-2)	(3)	(4-6)	(7, 8)	(9)	(10-12)	(13-16)	(17-19)	(20 - 25)	(26-28)	(29,30)	(31-33)	(34,35)	(36) 37-40	(41) 42-45	(46) 47-50
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TASK: DRIVE

SUBJECT

TASK ID	S #	DATE	DAY	CON	TASK #	TIME	TRIAL #	TIME MIN	SEC	$\frac{1}{100S}$	H.R. INIT	RR INT	H.R. MAX	RR MAX	$\int e\,dt$	TIME OFF COURSE
(1-2)	(3)	(4-6)	(7, 8)	(9)	(10-12)	(13-16)	(17-19)	(20	-	25)	(26-28)	(29,30)	(31-33)	(34,35)	(36-39)	[illegible]
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TASK: SAMPLE MEASUREMENT

SUBJECT

TASK ID	S #	DATE	DAY	CON	TASK #	TIME	TRIAL #	TIME MIN	TIME SEC	TIME $\frac{1}{100}$S	H.R. INIT	RR INT	H.R. MAX	RR MAX	d_E	d_S	Δd $d_E - d_S$
(1-2)	(3)	(4-6)	(7, 8)	(9)	(10-12)	(13-16)	(17-19)	(20	-	25)	(26-28)	(29,30)	(31-33)	(34,35)	(36-40)	(41-45)	(46-50)
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TASK: AUDIO BALANCING

SUBJECT

TASK ID	S #	DATE	DAY	CON	TASK #	TIME	TRIAL #	TIME MIN	SEC	$\frac{1}{100S}$	H.R. INIT	RR INT	H.R. MAX	RR MAX	f_E	f_S	Δf $f_E - f_S$
(1-2)	(3)	(4-6)	(7, 8)	(9)	(10-12)	(13-16)	(17-19)	(20	-	25)	(26-28)	(29,30)	(31-33)	(34,35)	(36-39)	(40-43)	(44-47)
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TASK: NAVIGATE SUBJECT:

TASK ID	S #	DATE	DAY	COND	TASK #	TIME	TRIAL #	TASK TIME	H.R. INIT	R.R. INIT	H.R. MAX	R.R. MAX	θ_{E_1}	θ_{S_1}	$\Delta\theta_1$ $\theta_{E_1} - \theta_{S_1}$	θ_{E_2}	θ_{S_2}	$\Delta\theta_2$ $\theta_{E_2} - \theta_{S_2}$	Δd
(1-2)	(3)	(4-6)	(7-8)	(9)	(10-12)	(13-16)	(17-19)	(20-25)	(26-28)	(29-30)	(31-33)	(34-35)	(36-39)	(40-43)	(44-47)	(48-51)	(52-55)	(56-59)	(60-63)

```
      DIMENSION IFORM(10),TIMO(2),RHR(4),DSC(5),IFMT(10),STRX1(4,8),
     1STRX2(4,8),DSSX(8),DSSQ(8),STRL1(4),STRL2(4),AVP1(4,8),SDP1(4,8),
     2STRQ1(4,8),STRQ2(4,8),TX1(8),TX2(8),TXQ1(8),TXQ2(8),AVS1(8),
     3AVS2(8),SDS1(8),SDS2(8),TPX12(8),TPQ12(8),TAV(8),TSD(8),
     4AVP12(4,8),SDP12(4,8),AVT12(4),SDT12(4),SX(16)
      AP=NP1
      AP2=NP2
      IG2=2
      IG1=1
      REWIND 1
      PAUSE MOUNT
      REWIND 2
      REWIND 3
  100 FORMAT(I2,I1,I3,I2,I1,I3,I4,3I1,F2.0,F4.2,2(F3.0,F2.0),F4.1,F1.0,
     13F4.2)
  101 FORMAT(1H1,//2X,4HCON ,1X,3HDAY,2X,3HTSK)
  102 FORMAT(3X,I1,3X,I2,4X,I2)
  103 FORMAT(13X,5HMEANS,45X,19HSTANDARD DEVIATIONS)
  104 FORMAT(1X,3HSUB,2X,2HSP,2X,1HN,2X,10HTIME SEC  9HDELTA     11HDELTA
     1       5HHRI  5HRRI  5HHRM  5HRRM  ,10HTIME SEC  ,9HDELTA    ,
     211HDELTA        ,5HHRI  ,5HRRI  ,5HHRM  ,5HRRM  )
  105 FORMAT(1X,I3,2X,I1,    F4.0,F9.2,2F10.1,1X,4F5.0,F9.2,2F10.1,2X,
     14F5.0)
  106 FORMAT(1X, 6H SUM X)
  107 FORMAT(1X, 9H SUM X**2)
  108 FORMAT(7X,10HTIME       ,2(14HDELTA D       ),11HHRI          ,
     111HRRI          ,11HHRM          ,11HRRM          ,5HDAY  ,6HTASK  )
  109 FORMAT(7F12.2 ,2I5)
  110 FORMAT(1H1)
  111 FORMAT(//)
      READ(5,100)IFORM,TIMO,RHR,DSC
   25 WRITE(9,101)
      WRITE(9,102)(IFORM(5),IFORM(4),IFORM(1))
      WRITE(9,103)
      WRITE(9,104)
      IP=1
      IP2=1
   50 DO 55 I=1,10
      IFMT(I)=IFORM(I)
   55 CONTINUE
      DSSX(1)=DSSX(1)+TIMO(1)*60.0+TIMO(2)
      DSSX(2)=DSSX(2)+DSC(1)
      DSSX(3)=DSSX(3)+DSC(2)*60.0+DSC(3)
      DSSX(4)=DSSX(4)+RHR(1)
      DSSX(5)=DSSX(5)+RHR(2)
      DSSX(6)=DSSX(6)+RHR(3)
      DSSX(7)=DSSX(7)+RHR(4)
      DSSQ(1)=DSSQ(1)+(TIMO(1)*60.0+TIMO(2))**2
      DSSQ(2)=DSSQ(2)+DSC(1)**2
      DSSQ(3)=DSSQ(3)+(DSC(2)*60.0+DSC(3))**2
      DSSQ(4)=DSSQ(4)+RHR(1)**2
```

* * * AUTOMATH 1800 SOURCE PROGRAM LISTING* * * 00040814

EFN PROGRAM: UASTX2 JOB: MACEK 00715

```
      DIMENSION IFORM(10),TIMO(2),RHR(4),DSC(5),IFMT(10),STRX1(4,8),
     1STRX2(4,8),DSSX(8),DSSQ(8),STRL1(4),STRL2(4),AVP1(4,8),SDP1(4,8),
     2STRQ1(4,8),STRQ2(4,8),TX1(8),TX2(8),TXQ1(8),TXQ2(8),AVS1(8),
     3AVS2(8),SDS1(8),SDS2(8),TPX12(8),TPQ12(8),TAV(8),TSD(8),
     4AVP12(4,8),SDP12(4,8),AVT12(4),SDT12(4),SX(16)
      AP=NP1
      AP2=NP2
      IG2=2
      IG1=1
      REWIND 1
      PAUSE MOUNT
      REWIND 2
      REWIND 3
 100  FORMAT(I2,I1,I3,I2,I1,I3,I4,3I1,F2.0,F4.2,2(F3.0,F2.0),3(F1.0,
     1 F4.2))
 101  FORMAT(1H1,//2X,4HCON ,1X,3HDAY,2X,3HTSK)
 102  FORMAT(3X,I1,3X,I2,4X,I2)
 103  FORMAT(13X,5HMEANS,45X,19HSTANDARD DEVIATIONS)
 104  FORMAT(2X,3HSUB,2X,2HSP,2X,1HN,2X,12HTIME SEC     9HDELTA
     1        5HHRI  5HRRI  5HHRM  5HRRM   ,10HTIME SEC   ,9HDELTA     ,
     2                   5HHRI  ,5HRRI  ,5HHRM   ,5HRRM   )
 105  FORMAT(1X,I3,2X,I1,    F5.0,F9.2, F10.1,1X,4F5.0,F9.2, F10.1,2X,
     14F5.0)
 106  FORMAT(1X, 6H SUM X)
 107  FORMAT(1X, 9H SUM X**2)
 108  FORMAT(7X,10HTIME       , (14HDELTA D       ),11HHRI        ,
     111HRRI          ,11HHRM          ,11HRRM          ,5HDAY   ,6HTASK  )
 109  FORMAT(6F12.2 ,2I5)
 110  FORMAT(1H1)
 111  FORMAT(//)
      READ(5,100)IFORM,TIMO,RHR,DSC
      WRITE(9,100)IFORM,TIMO,RHR,DSC
  25  WRITE(9,101)
      WRITE(9,102)(IFORM(5),IFORM(4),IFORM(1))
      WRITE(9,103)
      WRITE(9,104)
      IP=1
      IP2=1
  50  DO 55 I=1,10
      IFMT(I)=IFORM(I)
  55  CONTINUE
      DSSX(1)=DSSX(1)+TIMO(1)*60.0+TIMO(2)
      DSSX(2)=DSSX(2)+ABS((DSC(1)*60.0+DSC(2))-(DSC(3)*60.0+DSC(4)))
      DSSX(3)= DSSX(3)+RHR(1)
      DSSX(4)= DSSX(4)+RHR(2)
      DSSX(5)= DSSX(5)+RHR(3)
      DSSX(6)= DSSX(6)+RHR(4)
      DSSQ(1)=DSSQ(1)+(TIMO(1)*60.0+TIMO(2))**2
      DSSQ(2)=DSSQ(2)+((DSC(1)*60.0+DSC(2))-(DSC(3)*60.0+DSC(4)))**2
      DSSQ(3)=DSSQ(3)+RHR(1)**2
      DSSQ(4)=DSSQ(4)+RHR(2)**2
```

* * * AUTOMATH 1800 SOURCE PROGRAM LISTING* * * 000408

EFN PROGRAM: UASTX4 JOB: E.DALLESKA 00714

```
      DIMENSION IFORM(10),TIMO(2),RHR(4),DSC(5),IFMT(10),STRX1(4,8),
     1STRX2(4,8),DSSX(8),DSSQ(8),STRL1(4),STRL2(4),AVP1(4,8),SDP1(4,8),
     2STRQ1(4,8),STRQ2(4,8),TX1(8),TX2(8),TXQ1(8),TXQ2(8),AVS1(8),
     3AVS2(8),SDS1(8),SDS2(8),TPX12(8),TPQ12(8),TAV(8),TSD(8),
     4AVP12(4,8),SDP12(4,8),AVT12(4),SDT12(4),SX(16)
      AP=NP1
      AP2=NP2
      IG2=2
      IG1=1
      REWIND 1
      PAUSE MOUNT
      REWIND 2
      REWIND 3
  100 FORMAT(I2,I1,I3,I2,I1,I3,I4,3I1,F2.0,F4.2,2(F3.0,F2.0),2(2F4.1,4X)
     1,3F4.1)
  101 FORMAT(1H1,//2X,4HCON ,1X,3HDAY,2X,3HTSK)
  102 FORMAT(3X,I1,3X,I2,4X,I2)
  103 FORMAT(13X,5HMEANS,45X,19HSTANDARD DEVIATIONS)
  104 FORMAT(1X,2HS ,12HTIME SEC     ,9HDELTA     ,9HDELTA     ,9HDELTA
     1,5HHRI  ,5HRRI  ,5HHRM  ,5HRRM  ,12H TIME SEC    ,9HDELTA     ,
     29HDELTA    ,9HDELTA    ,5HHRI  ,5HRRI  ,5HHRM  ,5HRRM  )
  105 FORMAT(I2,   F10.2,3F9.1,1X,4F5.0,11X  ,3F9.1,4F5.0)
  106 FORMAT(1X, 6H SUM X)
  107 FORMAT(1X, 9H SUM X**2)
  108 FORMAT(7X,10HTIME      ,3(14HDELTA D       ),11HHRI        ,
     111HRRI       ,11HHRM         ,11HRRM           ,5HDAY  ,6HTASK  )
  109 FORMAT(8F12.2 ,2I5)
  110 FORMAT(1H1)
  111 FORMAT(/ )
  112 FORMAT( 3H N=,I4, 4HPRD=I4)
      READ(5,100)IFORM,TIMO,RHR,DSC
      WRITE(9,100)IFORM,TIMO,RHR,DSC
   25 WRITE(9,101)
      WRITE(9,102)(IFORM(5),IFORM(4),IFORM(1))
      WRITE(9,103)
      WRITE(9,104)
      IP=1
      IP2=1
   50 DO 55 I=1,10
      IFMT(I)=IFORM(I)
   55 CONTINUE
      DSSX(1)=DSSX(1)+TIMO(1)*60.0+TIMO(2)
      DSSX(2)=DSSX(2)+ABS(DSC(1)-DSC(2))
      DSSX(3)=DSSX(3)+ABS(DSC(3)-DSC(4))
      DSSX(4)=DSSX(4)+DSC(5)
      DSSX(5)=DSSX(5)+RHR(1)
      DSSX(6)=DSSX(6)+RHR(2)
      DSSX(7)=DSSX(7)+RHR(3)
      DSSX(8)=DSSX(8)+RHR(4)
      DSSQ(1)=DSSQ(1)+(TIMO(1)*60.0+TIMO(2))**2
      DSSQ(2)=DSSQ(2)+(ABS(DSC(1)-DSC(2)))**2
```

```
      DO 360 IP=1,NEP
      WRITE(9,104)(IFMT(5),IFMT(4),IFMT(1),IP      ,STRL1(IP),(AVP12(IP,
     1J),J=1,6),(SDP12(IP,J),J=1,6))
      WRITE(3)((STRX1(IP,J),J=1,6),(STRQ1(IP,J),J=1,6),IFMT(4),IFMT(1))
      N=N+1
  360 CONTINUE
C  GRAND TOTAL FOR DAY
      DO 365 J=1,6
      TPX12(J)=TX1(J)+TX2(J)
      TPQ12(J)=TXQ1(J)+TXQ2(J)
  365 CONTINUE
      TTRL12=TTRL1+TTRL2
      TP12=NP1+NP2
      DO 375 J=1,6
      TAV(J)=TPX12(J)/TTRL12
      TSD(J)=SQRT((TTRL12*TPQ12(J)-TPX12(J)**2)/(TTRL12*(TTRL12-1.0)))
  375 CONTINUE
      WRITE(9,105)(IFMT(5),IFMT(4),IFMT(1),TTRL12,(TAV(J),J=1,6),
     1(TSD(J),J=1,6))
      WRITE(3)((TPX12(J),J=1,6),(TPQ12(J),J=1,6),IFMT(4),IFMT(1))
      N=N+1
C CLEAR ALL ARRAYS
      IP=0
      DO 355 IP=1,NEP
      STRL1(IP)=0.0
      STRL2(IP)=0.0
      DO 355 J=1,8
      STRX1(IP,J)=0.0
      STRQ1(IP,J)=0.0
      STRX2(IP,J)=0.0
      STRQ2(IP,J)=0.0
  355 CONTINUE
      DO 390 J=1,6
      TX1(J)=0.0
      TXQ1(J)=0.0
      TX2(J)=0.0
      TXQ2(J)=0.0
  390 CONTINUE
      TTRL1=0.0
      TTRL2=0.0
      TRL2=0.0
      TRL1=0.0
      GO TO(50,50,405,405,405),M
C CHG DAY
  400 M=3
      GO TO 201
  405 WRITE(9,110)
      WRITE(9,106)
      WRITE(9,107)
      ENDFILE 3
      REWIND  3
```

APPENDIX IV

MINNESOTA MULTIPHASIC PERSONALITY INVENTORY EVALUATIONS

APPENDIX IV

MINNESOTA MULTIPHASIC PERSONALITY INVENTORY EVALUATIONS

The Minnesota Multiphasic Personality Inventories administered to the subjects on their first and eighteenth day in the simulator was analyzed by Mr. Floyd Akers, phychologist of the American Rehibilitation Foundation, Minneapolis. Because of the personal nature of this test, this appendix is published as a separate document and is available for limited distribution through the office of Dr. Stanley Deutsch, OART, Washington, D.C.

ERRATA

for

Honeywell Interim Technical Report 12504-ITR2, Man System Criteria for Extraterrestrial Roving Vehicles - Phase IB - The LUNEX II Simulation (MFSC Contract NAS8-20006), 15 June 1966

Page 89 - Table 21: Footnote c) should read "...from Figures 92 and 94" (instead of Figures 80 and 82); Footnote d) should read "...from Figures 96 and 97" (instead of Figures 84 and 85).

Pages 190-193 - Figures 92 through 95: Ordinate scale callouts should read "Oxygen Consumption Rate (L/Min) and Heart Rate (Beats/Min x 100)".

Page 195 - Figure 97: Abscissa scale is displaced one unit; it should begin at 40 and end at 200 (as in Figure 96).